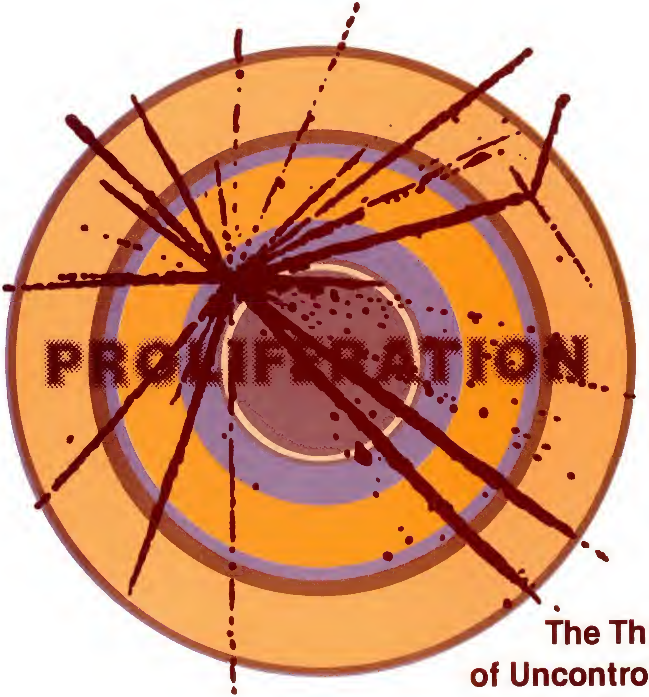
May 1975 $1.25

THE bulletin OF THE ATOMIC SCIENTISTS

a magazine of science and public affairs



The Threat of Uncontrolled Nuclear Spread

THE DRIFT TOWARD DISASTER
Your gift to Pugwash will help reverse it

". . . the present deployment of weapons and forces in Europe makes it possible that even if violence erupts accidentally, it is likely to escalate very rapidly. In particular, the presence of large numbers of nuclear weapons in Europe is a major factor in making such rapid escalation likely."

This is one of the conclusions reached by a Pugwash symposium held last year in Cracow. This view, generally subscribed to by scientists from eastern and western Europe, points up the dangers we face in the realm of arms control.

In the January issue of the *Bulletin* Dr. Bernard Feld wrote: *without effective means of preventing the independent development of nuclear weapons by capable nations, and without effective safeguards against the diversion of nuclear weapons materials . . . it will be impossible to prevent nuclear weapons falling into irresponsible hands.*

Treaty Review Conference

We are now approaching the Nuclear Non-Proliferation Treaty review conference. This conference could be crucial, for if it fails to deal with these problems then the drift toward accidental disaster will accelerate and the final disaster will become increasingly inevitable.

Peace Under Pressure

But one of the frightening conclusions reached by the gathering of eminent scientists, many of them Nobel Prize winners and academicians, at Cracow, was that the armaments race and nuclear proliferation are not fundamentally due to conflict between nations. Rather, there are vested interests in military and industrial circles in every nation which drive their nations into the dangerous path of arms escalation.

Doves Unite

Some effective force must identify these interests and present the case for peace. There must be a forum for the doves to combine to press for their vested interest: peace and the survival of life on this planet. The forces of science and technology must speak out in a clear objective voice for peace.

Such a forum exists. It is working and working effectively. It is Pugwash, the group of scientists and concerned citizens who laid the basis for the Nuclear Non-Proliferation Treaty in 1968 and who continue to strengthen it now.

Danger For Pugwash

But Pugwash itself is in danger. Dependent as it is on private donations, its financial base has always been insecure. Now it faces disaster. Inflation and the drying up of grants have taken their toll and this situation cannot continue. Pugwash may be the best hope for peace we have. Pugwash needs the support of doves everywhere—Pugwash needs your support.

Friends In Need

Now is the time when Pugwash is most needed by a world deteriorating into chaos; and now is the time when Pugwash's need is greatest. You can help by becoming a *Friend of Pugwash*. As a *Friend* you will be kept up to date on Pugwash meetings and publications. Your contributions, of course, will be fully tax-deductible.

A $100 donation enrolls you as a *Friend of Pugwash*. Students and those unable to contribute $100 can enroll as associate members for $25. Please don't delay. Fill out the coupon or send your check with the information requested.

☐ Please enroll me as a *Friend of Pugwash* and send me summaries of its major meetings. I enclose $100 as my **1975-76** contribution.

☐ Please enroll me as an associate member of *Friends of Pugwash* and send me digests of its important meetings. I enclose $__________

Make Cheque payable to BAS Pugwash and mail to the Academy of Arts and Sciences, 165 Allandale St., Jamaica Plain Station, Boston, Mass., 02130.

Name ____________________
Address ____________________
City ____________________
State __________ Zip Code __________

All contributions are tax deductible

EDM
EMBOSOGRAPH DISPLAY MFG. CO.
VISUAL AIDS DIVISION CHICAGO, ILLINOIS 60614

THE bulletin OF THE ATOMIC SCIENTISTS

a magazine of science and public affairs

MAY 1975 VOLUME XXXI NUMBER 5

Founded in 1945 by Hyman H. Goldsmith and Eugene Rabinowitch. Published by the Educational Foundation for Nuclear Science. The Bulletin Clock, symbol of the threat of nuclear doomsday hovering over mankind, stands at nine minutes to midnight.

STAFF

Editor-in-Chief, Eugene Rabinowitch, 1901-1973

Editor, Samuel H. Day, Jr.; Managing Editor, Susan Cullen; Production Manager, Ann D. Foley; Subscription Manager, Janet Feller Hyde; Bookkeeper, Jeanette Williams; Staff Writer, Jane Wilson; Art Consultants, Les Siemens, Deborah Bright.

BOARD OF DIRECTORS

Robert M. Adams
Ruth Adams
R. Stephen Berry
Charles S. Dennison
Bernard Feld
Robert Gomer

Walter J. Blum
Legal Counsel

Franklin Long
Eugene H. McLaren
Donald H. Miller, Jr.
Victor Rabinowitch
Stuart Rice
Ezra Sensibar
William Swartz
Hans Zeisel

Editorial Advisory Board: Ruth Adams, Frank von Hippel.

Sponsors: Hans A. Bethe, chairman, Samuel K. Allison, Robert F. Bacher, Detlev W. Bronk, A.H. Compton, E.U. Condon, F. Daniels, Albert Einstein, James Franck, Bentley Glass, S.A. Goudsmit, T.R. Hogness, F.W. Loomis, Philip M. Morse, H.J. Muller, J. Robert Oppenheimer, Linus Pauling, G.B. Pegram, I.I. Rabi, Julian Schwinger, Frederick Seitz, John A. Simpson, Cyril S. Smith, Leo Szilard, Harold C. Urey, V.F. Weisskopf, Hugh C. Wolfe, Sewall Wright, J.R. Zacharias.

Editorial and advertising correspondence should be addressed to Bulletin of the Atomic Scientists, 1020-24 E. 58th Street, Chicago, Ill. 60637. Manuscripts must be submitted in duplicate and accompanied by a self-addressed envelope and return postage. Letters to the editor should be limited to 500 words.

Subscription correspondence should be addressed to Bulletin of the Atomic Scientists, Circulation Department, 1020-24 E. 58th Street, Chicago, Ill. 60637. Please allow 5 weeks for change of address. Include your old address as well as your new address and, if possible, an address label from a recent issue.

BULLETIN OF THE ATOMIC SCIENTISTS is published monthly ten times a year (suspending publication in July and August). Second class postage paid at Chicago, Illinois, and at additional mailing offices. Subscription rates: U.S.—1 year, $15; 2 years, $26; 3 years, $35. Canada and Pan American Union—1 year, $15.50; 2 years, $27; 3 years, $36.50. Other countries—1 year, $17; 2 years, $29; 3 years, $39. Copyright 1975 by the Educational Foundation for Nuclear Science, 1020-24 E. 58th Street, Chicago, Ill. 60637. (312) 363-5225.

2 Letters

COMMENT

3 Elastic Statistics / David Dinsmore Comey

EDITORIALS

5 Making the World Safe for Plutonium / Bernard T. Feld

6 The Nuclear Debate / Frank von Hippel

ARTICLES

8 The Spread of Nuclear Weapons—Is the Dam About to Burst? / Thomas A. Halsted

12 Terrorists Keep Out! / Mason Willrich

17 The Special Case of Chemical and Biological Weapons / J. P. Perry Robinson

24 Big Bangs from Little Bombs / Barry Schneider

29 'Peaceful' Nuclear Explosions / Alva Myrdal

34 The Importance of Point of View / Robert Gomer

'ALL IN OUR TIME'

40 A Foul and Awesome Display / Kenneth T. Bainbridge

BOOKS

47 "Society and the Assessment of Technology," by François Hetman, "Environmental Harrassment OR Technology Assessment," by Derek Medford, "Technology Assessment in a Dynamic Environment," ed. by M. J. Cetron and B. Bartocha, and "Technology Assessment and the Quality of Life," ed. by G. J. Stober and D. Schumacher / Alan L. Porter and Steven H. Flajser

48 "Genetic Fix," by Amitai Etzioni / R. D. O'Brien

Credits: Cover design by Les Siemens. Interior art by Deborah Bright. Photographs in this issue: U.S. Navy, 9; U.S. Army, 24; Los Alamos Photographic Laboratory, 40-43. Artists in this issue: Susan Daniels, 17; Sidney Harris, 19; Rainey Bennett, 44.

THIS ONE

9C1Z-EUW-4FAN

LETTERS

A Critique

My congratulations for your fine editorial, "The Lessons of Watergate" by Samuel H. Day, Jr. (*Bulletin*, March 1975). The recent confirmation of American subversion of the Allende government in Chile further supports your position.

In the past I have been critical of the *Bulletin* for not being more outspoken politically and for not publishing more and better written reviews of the increasing number of books on science and public affairs. Recent issues of the *Bulletin* answer the first criticism. I hope something can be done about the second, for incisive reviewing helps raise the level of discourse.

As an historian of science let me add that the *Bulletin's* historical series, "All in Our Time," dealing with the development of the atomic bomb, is indeed valuable.

Harold Fruchtbaum
School of Public Health
Columbia University
New York, N. Y.

The Scientists' Role

In his letter to the editor (*Bulletin*, Feb. 1975), Olaf Tellefsen criticizes scientists for lacking "the backbone to take a firm position on current world problems and force the government to comply."

Tellefsen assumes that scientists agree about what the problems are and how they should be resolved. But that has never been true in the past, nor is it true today. Fritz Haber believed that in time of war a scientist's duty was to help his country win even if it required that he invent poison gas and administer its use. Sir Humphrey Davy believed that while govenments may be at war, "the men of science are not." Who should speak for science today, Wigner and Teller or Pauling and Wald?

There is but one bond that unites scientists. It is the work they do as scientists. Tellefsen seems to think it is different with garbage collectors and coal miners, but it is similar with them. Garbage collectors and coal miners agree about wages, working conditions, and the efforts they must make to achieve these. Scientists agree about the need to support research. These are positions derived from work interests. To take a firm position on current world problems is a political matter. Political judgments are not defined by occupation. Would Tellefsen's engineering colleagues agree with him in his political judgments? They are in a better position than scientists to exact terms from the government. Should the engineering fraternity decide to put pencils down, the development of new horror weapons would come to a halt. Is it reasonable to expect this to happen?

All of us, scientists and non-scientists, must make sane, humane compassionate political judgments if we are to survive. Scientists can help the rest of us by informing us in a language we can understand so that we will join together to stop the constant growth of overkill before the clock runs out.

The *Bulletin* has made an invaluable contribution to this effort.

Lazer Goldberg
Hofstra University
Hempstead, N. Y.

Energy for Fertilizer

Amory Lovins' comprehensive article on world energy requirements ("World Energy Strategies," *Bulletin*, May–June, 1974) contained a claim that by the year 2000, world nitrogen fertilizer need would be 800 billion kilograms per year, yielding an energy requirement equal to 20 percent of present world energy production.

There must have been an error somewhere in Lovins' calculations since 800 billion kilograms of nitrogen would require covering all of the world's arable surface with almost 550 kilograms of nitrogen per hectare. Based on current usage rates, and recognizing the upper limits to increased fertilizer use on any given hectare, a more realistic estimate of use in the year 2000 would fall in the range of 100–150 billion kilograms of nitrogen.

To add further perspective, the United States currently produces and uses about 20 percent of the world's nitrogen supply. It requires about 2 percent of the total natural gas supply of the United States to produce this nitrogen plus all ammonia produced for other uses. Using current technology, a 50 percent expansion in nitrogen production would require an additional one percent of the present U.S natural gas supply. Energy is required to produce fertilizer, but hardly so much that energy will be *the* fertilizer problem.

John R. Douglas, Jr.
David A. Patterson
Tennessee Valley Authority
Knoxville, Tenn.

The author replies: Douglas and Patterson are right to suggest that world consumption of nitrogen in fertilizer will in fact be less than 800 billion kilograms per year in the year 2000. My own guess is 30 to 100 billion kilograms per year for a population of three to five billion, assuming only moderate discontinuities meanwhile.

The approximately 800 billion kilograms of nitrogen per year mentioned in my paper, however, is not a computational error. It can be derived naively by extrapolating recent nitrogen consumption at exponential rates slightly below those prevailing in the mid-1960s, or more rationally by combining projections of new crops, areal expansion, and areal intensification with observed diminishing returns in nitrogen takeup (saturation is typically at about 500 kilograms of nitrogen per hectare per year in temperate agriculture) and with increased nitrogen runoff in rainy areas.

Various technological optimists have presented similar projections. Roger Revelle, for example, envisages—admittedly somewhat after the year 2000—cultivating 5 billion hectares for food (and a tenth as much for non-food crops) at roughly the intensity of the Iowa corn farmer or the West German farmer, that is, about 130 kilograms of nitrogen per hectare per year.[1] This would imply a world total of about 700 billion kilograms of nitrogen per year, which I think is ecologically, economically, and logistically implausible.

Douglas and Patterson, taking the presently cultivated area of about 1.4 billion hectares, derive an intensity of about 550 kilograms of nitrogen per hectare per year. Clearly if the *potentially* arable total of about 3.2 billion hectares were considered instead, the intensity would be about 250 kilograms of nitrogen per hectare per year, well below saturation for many crops. I do not say that this is credible or desirable, but many other people think it is; I merely repeat their curious notions.

Georg Borgstrom agrees that "If energy-intensive farming of the kind practiced in the United States, the United Kingdom, and parts of the Nordic countries were applied worldwide and were to give the present world population a corresponding nutritional standard, this would require some 35 to 40 percent of the total world energy account. This is completely beyond the realm of possibility"[2]—and hence, together with many other constraints, leads me to think that the U.N. population projections based on declining mortality rates are unrealistic. But that is another paper!

Amory B. Lovins
Friends of the Earth Ltd.
London, England

[1] Revelle, U.N. paper, E/CONF 60/SYM 13, autumn 1973.

[2] Borgstrom, *Ambio*, 2:6 (1973), 214.

ELASTIC STATISTICS

DAVID DINSMORE COMEY

David Dinsmore Comey is director of environmental research for Business and Professional People for the Public Interest, a non-profit corporation in Chicago which is involved in solving urban and environmental problems.

Shortly after I delivered my testimony on nuclear plant unreliability to the Federal Energy Administration in September 1974 (*Bulletin*, Nov. 1974), the Nuclear Regulatory Commission—the federal agency that is the regulatory successor to the AEC—started "improving" nuclear plant capacity factors by switching from the traditional basis of "design capacity" to a new concept called "maximum dependable capacity" (MDC).*

For example, the Palisades (Mich.) nuclear plant, although designed to produce 821 megawatts of electricity, was reduced to 700 megawatts by switching to MDC; Turkey Point (Fla.) units 3 and 4 similarly metamorphosed from 745 megawatts each to 666.

"Maximum dependable capacity" is defined by the NRC as a plant's net output during the most restrictive seasonal condition for condenser cooling efficiency. This usually occurs only for a short time during the hottest month of the year, but the NRC applies it to the entire year of the plant's operation, which is like computing a golfer's handicap solely on the score he got during a New Year's Day blizzard while hung over.

Any Soviet factory manager would instantly recognize MDC as an implementation of the time-honored technique of "overfulfilling the norm" by setting the norm below expected production.

As a result of using MDC, the NRC managed to have four nuclear plants running at more than 100 percent capacity factors during December 1974.

For the 28 nuclear plants larger than 100 megawatts that operated commercially throughout 1974, the NRC's average capacity factor, weighted by megawatt capacity, is 54.4 percent using MDC. Computed using the accepted definition of capacity factor, these plants had a weighted average of only 52.4 percent. The comparable 1973 average was 58.4 percent, so their 1974 record was worse.

If NRC continues this fiction, the 1975 figures will show an even greater spread: (1) nearly all the new plants coming on line are taking advantage of MDC to "derate" themselves; and (2) only 4 of the above 28 plants have so far significantly increased their capacity factors by using MDC, and the majority seem blissfully ignorant of its possibilities.

***Capacity factor is normally calculated by dividing the electrical megawatt-hours produced by a plant during a given time period by the product of the design capacity of the plant (in electrical megawatts) times the number of hours in the same time period. Capacity factor is thus a measure of the electricity actually produced by a plant compared to what it could have produced.**

Pistons vs. Turbines

I read with interest James Cicarelli's article "Whatever Happened to the Turbine Car" in the December 1974 issue of the *Bulletin*. The Ford Motor Company would agree that the turbine has the potential of becoming the passenger car engine of the future; however, it is by no means ready yet, despite our many years of research. We have had, and are continuing to have, a major research effort to develop a satisfactory passenger car turbine. However, the development of a satisfactory passenger car turbine is a difficult problem as it involves the development of new materials.

I'd like to make clear our approach at Ford. First I wish to state that I was disturbed at the conclusion that the automotive industry had "forsaken the turbine car" because of "(1) the vested interest Detroit has in the piston engine, and (2) the make-up of the U.S. auto industry, which, by its very nature, discourages innovation." This is simply not so. The fact is that we are actively pursuing several innovative alternative engine programs.

Ford has had a very substantial research program on passenger car turbines since the early 1950s with the exception of a three-year period starting in 1960 when our major effort was on a large turbine for military application. In 1966 Ford had a passenger car turbine engine running in a Thunderbird which did demonstrate good fuel economy at high speed. However, fuel economy was significantly deficient in city-suburban type driving compared to the piston engine of that day, and the cost of engines in volume production would have been more than twice that of the 1966 piston engine. To our knowledge, no passenger car turbine engine has since been demonstrated that significantly improves on that 1966 engine in fuel economy or cost.

In 1967 Ford made the decision that in order to attain fuel economy significantly better than the piston engine, operating temperatures would have to be raised to 2,500 degrees Farenheit from the 1,900 degrees then attainable. As the superalloys used would only provide a 1,900 degree capability, this meant that alternative materials, such as ceramics, had to be investigated and methods of fabricating them developed. Since 1967 the majority of our passenger car turbine effort has been devoted to development of ceramics to replace the superalloys and we believe that this approach will solve both the fuel economy and cost problems. Since 1971 approximately half of this effort has been supported by the Department of Defense at an annual rate of about $2.5 million.

Cicarelli's article indicated that emission of oxides of nitrogen is an extremely difficult problem and we would agree. However, recent laboratory tests at Ford give high confidence that the most stringent nitrogen oxide emission requirements can be met with careful further development even for the 2,500 degree engine. One of our competitors has recently announced that under laboratory conditions it has also met these low nitrogen oxide requirements at the lower operating temperatures.

We believe that in order for the turbine to be viable from an environmental, energy, and economic point of view, it must have fuel economy at least equal to other alternative power plants. It must be able to meet the most stringent emission requirements, and attain a cost level reasonably comparable to a fully emissionized piston engine. To attain these objectives will take several years and several million dollars, an effort that represents a considerably faster rate than we can allocate at this time to a high risk venture. Successful engine development would be followed by four years of facilities development and tooling which means that one should not expect to see a passenger car turbine in production before the mid-1980s at the earliest.

Further, if any new engine were to completely supplant the piston engine, it would take at least 10 years after the start of production for a complete changeover. It is probable that neither the machine tool industry nor the American economy could support a faster rate of change. We can, therefore, expect to see the piston engine around for a good many years. In the meanwhile, there are significant improvements in piston engines coming along that approach the potential of the turbine, such as certain versions of the stratified charge engine.

In summary, the turbine engine does offer real potential for passenger car application. The road to get there will be long and costly but I wish to assure your readers that our alleged "vested interest in piston engines" is in no way a barrier to our effort.

Harold K. Sperlich
Vice President
Product Planning and Research
Ford Motor Company

The author replies: By the mid-1960s, Chrysler believed, as evidenced by its published materials, that the turbine engine was economically feasible, if not in passenger cars, at least in trucks, buses, and select military vehicles. Had Chrysler gone into even a limited turbine production then, the 10 years Sperlich suggests are necessary for the successful development and retooling for a passenger turbine car would have elapsed by now, and society could be presently enjoying the benefits of this innovation. Instead, it will be, by Sperlich's own admission, the mid-1980s at the earliest before one can expect a mass-produced turbine car. If that isn't an example of technological inertia, I don't know what is.

James Cicarelli
State University of New York
Oswego, N.Y.

Nuclear Flack

I strongly object to such 'political puffery' as the A. Robert Smith article on Mike McCormack ("The New Scientist-Advocates," *Bulletin*, Feb. 1975). If this reporter is familiar with the Northwest, as you state, he knows that the representative from Hanford is a dedicated flack for the nuclear establishment.

Presently, he is pushing for Hanford to be the nation's first nuclear waste depository using concrete-wrapped canisters. On Feb. 4, 1975 he spoke to the Washington State Legislature extolling the nuclear power industry and discounting any criticism as scare stories. He sounds remarkably like another Washingtonian salesman for the industry, Dixy Lee Ray.

Before McCormack went to Congress, he was very busy pushing legislation favorable to the utilities and unfavorable to the citizens.

We citizens of Washington state are seemingly slated to be the base for nuclear plant proliferation for power sales outside the state. Our politicians are willing to have the Hanford area become a massive nuclear park. We citizens have no voice in the decisions, for the utilities, both public and private, control the legislature.

Last June we wrote a plank in the state Democratic party platform advocating a moratorium on nuclear plant construction until safety and siting problems were resolved. Most prominent in the stifling of any public debate on this matter were the campaign managers for Mike McCormack. We had to agree to vote without debate on this matter and upon winning, we were personally vilified by McCormack's home county delegates!

Energy bills sponsored by our man from Hanford still send the lion's share of funds to the nuclear establishment. When that changes—or when McCormack votes for abolition of the Price-Anderson Act—I'll begin to believe his rosy statements of our good fortune in having "our nuclear industry as well advanced as we find it today, ready to provide much of the energy this nation will need during the next 50 years."

Margaret Yeoman
Anacortes, Wash.

A Question

I have been an avid reader of the *Bulletin* since it began. But how did that joker, Kolodiy ("Velikovsky: Paradigms in Collision," by George Kolodiy, *Bulletin*, Feb. 1975), get into this last issue with the ghost of Velikovsky? May we assume that since the disappearance of Dr. Rabinowitch the current editor is not a scientist?

Carl O. Dunbar
Dunedin, Fla.

Editor's response: The current editor is a journalist, as was the late scientist editor-in-chief, Eugene Rabinowitch.

Making the world safe for plutonium

BERNARD T. FELD

Thirty years ago, the atomic scientists—fresh from their experiences of the wartime atomic bomb projects—warned the world of the dangers of the proliferation of nuclear weapons. In their naivete, they proposed the creation of an international atomic energy authority, which would have an absolute monopoly over all nuclear energy programs, as a means of ensuring the universal availability of the benefits of nuclear fission while avoiding the spread of its capacity for destruction.

The world was then not ready for such a drastic, though logical step. Since then, even as the benefits of peacetime nuclear power have been much slower in arriving than was predicted by the early enthusiasts, so also has the number of nuclear-weapons states grown less rapidly than the spread of technology would have permitted. However, the restraints which have been exercised by most of the nuclear-capable nations—be it for economic or political reasons—have not been matched by the so-called great powers. Their nuclear arsenals have been growing at an accelerating pace, while the doctrines which have until now inhibited their use are being insanely eroded by the siren songs of the advocates of *limited* nuclear war.

Indeed, those who believe that the past self-imposed prohibitions, against nuclear weapons production and their use, are likely to be maintained in an age of growing dependence on nuclear power are living in a nuclear fool's paradise. The international arrangements upon which this hope has been based—the Nuclear Non-Proliferation Treaty (NPT)—has been woefully inadequate for its purposes. Only 82 nations have so far ratified it, and these do not include such technically-capable countries as Brazil, Egypt, India, Israel, and Japan—not to speak of France and the People's Republic of China. Even among the 16 who have signed but not yet ratified the NPT—for example the twice-burned Japanese—there are growing internal arguments against ratification, on the pretext of keeping open the nuclear weapons option. Pressures on the nonproliferation dam are growing; last year's test on a nuclear device by India is perhaps the most obvious crack, but there are numerous fissures, visible to all who bother to look.

The greatest dangers come from the rapidly growing proliferation of nuclear technology to all corners of the globe and, especially, the growing rate of production and availability of plutonium as an inevitable concomitant of most peaceful nuclear power programs. Plutonium, an unstable element not normally found in nature, is produced as a by-product in any nuclear reactor containing either normal or somewhat-enriched uranium. The rate of its production depends on the type and design of the reactor. Since the bulk of the plutonium produced could be re-used in the power cycle, as a substitute for the rare component of uranium (that is, uranium-235, which is present in normal uranium in the proportion of only one part in 140), upon which the power production depends, it is generally regarded as economically advantageous to produce as much plutonium as is feasible in a given reactor. Furthermore, since plutonium is a different element from the uranium from which it is derived, its separation from the parent uranium can be achieved by relatively simple chemical techniques (albeit greatly complicated by the presence of vast quantities of radioactive products from the fission of the original fuel in the reactor). In contrast, the separation of the fissionable uranium-235 from the bulk of normal uranium (uranium-238), in which it is present in natural sources, requires extremely difficult and power-consuming physical processes.

However, two problems arise in a nuclear power cycle which involve the production and recovery of plutonium. First, plutonium is one of the most poisonous substances known; the ingestion of only a few millionths of an ounce can prove fatal to the unlucky individual concerned, although its lethal effects take some time to manifest themselves. Second, plutonium can be used to make nuclear weapons.

Until now, the production of plutonium (and highly enriched uranium-235) has been confined to a handful of technically advanced nations, which together are producing a few tens of tons per year (enough for a few thousand bombs). Although most of this is confined to the nuclear-weapon states, and associated with their weapons programs, there are a number of non-weapon states (e.g., India, Federal Republic of Germany, and Israel) in which the production capabilities are non-negligible. Many, but by no means all, of the peacetime power programs are currently subject to the "safeguard" controls of the International Atomic Energy Agency (IAEA) under a sort-of laissez faire arrangement in which each nation negotiates with the IAEA a separate agreement for the safeguarding of the fissionable materials in certain plants, in which the Agency's role is partly that of inspector and partly that of supervisor or verifier of national inspection systems.

Within its limitations, the current IAEA safeguard system operates as effectively as can be expected; the agency group is technically competent and devoted to its tasks. But what is just barely operable in 1975 will be hopelessly inadequate in the coming decades. Instead of requiring the safeguarding of plutonium and uranium programs in the non-weapon states which are capable of producing some tens of bombs per year, current projections call for safeguarding nuclear power programs producing enough plutonium—in the developing world alone—for some 1,000 bombs per year in 1980 and around 30 times more in the year 2000. (The production in the developed nations is expected to be approximately 7 to 10 times greater.) At the same time, we are witnessing a fierce competition among the nuclear developed countries to sell nuclear technology, plants and equipment in the developing world, with little if any regard to the inevitable consequences for nuclear weapons proliferation.

There are many who believe that we have already passed the point of no return, as far as nuclear weapons proliferation is concerned. Indeed, some so-called military strategists in the West even profess to find some virtue in inevitability. But I believe that prudent and peace-loving individuals and governments cannot accept this view. Instead, all possible efforts must be concentrated on devising and effectuating measures for strengthening the nuclear floodgates.

The immediate target of such efforts should be the conference convened by the United Nations in Geneva this month to review the status of the Non-Proliferation Treaty. Assuming that the major nuclear powers can achieve agreement on measures to strengthen the NPT, and to bring into its regime those nations still remaining outside, much could be accomplished in Geneva.

The required measures include:

1. An unconditional agreement among all the nuclear "haves" to refuse any assistance in the nuclear realm to any nation not adhering to the NPT.

2. An agreement that all plutonium processing—from its extraction from the spent reactor fuel elements through its processing and final fabrication into new fuel elements and their installation into the nuclear reactors—shall be performed in a very few, centralized, heavily protected and guarded international facilities under the strictest possible international control. The same measures are required for highly-enriched uranium-235 and, eventually, for the production of uranium-233, which can be bred from thorium in nuclear reactors.

3. A thorough re-examination of current nuclear programs, with a view to minimizing dependence on fuel cycles which require the recycling of plutonium or the production of uranium-233 or very highly enriched uranium-235. The widely-held idea that the economics of nuclear energy demand the conversion of uranium-238 into plutonium may, in fact, be a myth—especially if nuclear fission energy is regarded as an interim solution that is needed to tide us over a temporary energy crisis for the remainder of this century.

Thus, emphasis should be placed on the development of reactors utilizing natural uranium, and on schemes which permit the storage or burial of the spent fuel elements *without* the extraction of the plutonium. Heavy water and graphite moderated reactors are especially suited to such practice, and appear to be economically competitive. Most especially, the reliance on a nuclear energy cycle involving "breeder" reactors should be strongly discouraged.

The adoption of such measures, as an integral part of the NPT regime, will not be easy. The pressures are all in the opposite direction—toward increased nuclear anarchy and a loosening of controls. It will be necessary for the nuclear "haves" to pay a price, both economically and politically. Aid in their nuclear programs to those developing nations that accept the NPT will need to be generous; accessibility to the internationally-controlled facilities will need to be guaranteed to all qualified and reasonable users; and political measures will need to be devised and implemented for assuring the security against nuclear attack or blackmail to those countries that willingly forego an independent nuclear weapons capability while the nuclear superpowers will need to accelerate their own nuclear disarmament.

Unfortunately, the advanced nations, whose unified acceptance of a program such as outlined above is essential, do not now appear to be thinking or moving in this direction. And time is running out.

Clearly, the strongest public pressures are required on the governments concerned, to convince them to approach these problems with the seriousness that is called for by the present situation. If such pressures can be mobilized in time, it may still be possible to reverse the trend—to rescue the NPT review conference from the disastrous shambles toward which it now seems to be heading.

The nuclear debate

FRANK von HIPPEL

Nuclear power has become the focus of a great controversy over the past few years—and the debate has become increasingly polarized into an all or nothing battle.

On the one side a coalition of nuclear opponents has developed, with Ralph Nader as its chief political spokesman and with a number of very able and articulate scientists as technical advisors; it incorporates the new attitude of awareness and concern achieved by the environmental movement. This coalition sees in nuclear power the potential for catastrophic accidents and sabotage at nuclear power plants, for diversion of nuclear materials into the manufacture of terrorists' weapons, and for the pollution of the environment with long-lived radionuclides—plutonium in particular. During the past months, this coalition of nuclear opponents has finally made the mass media aware of the issue—and we have had story after story on the perils of nuclear power.

On the other side are arrayed the Administration, the utilities, the reactor manufacturers, and another group of independent scientists for whom Hans Bethe, the Cornell physicist, has recently emerged as the most respected spokesman. This group believes that the hazards of nuclear power can be contained and that, even with current technology, the perils of going ahead with nuclear power are much less than those associated with not going ahead—and now we have the supporters of nuclear power mounting a new public relations offensive.

One fortunate result of the debate is that many of the important problems of nuclear power are now receiving much more attention from the new Nuclear Regulatory Commission—and from the technical community as a whole—than they have received in the past. An unfortunate result is that these gains will be lost if the process of polarization continues to the point where everyone who enters into the debate is forced to choose between just two extreme positions: Stop nuclear power or let the current technology proliferate without improvement. Many of the statements from both sides have been put in essentially these terms, and have therefore served more to confuse than to educate the public about the true degree of risk from nuclear power and the possibilities which exist for reducing the risk.

There is a strong case to be made for nuclear power. It is not at all certain that we can do without it—at least for the near future. Furthermore, the dangers associated with oil and coal may be even greater than those from fission power. Of special concern are the international instabilities associated with the oil economy and the devastating climatic changes which might result from our ever-increasing consumption of fossil fuels—coal in particular. Obviously our energy consumption has reached a level where, with our current arrangements at least, the side-effects associated with its production pose many major hazards to the social order and the world environment.

At the same time, it is obvious to every knowledgeable person that our current nuclear energy system is far from its practical technological limits in achieving the goals of safety and environmental compatibility. In the past nuclear power policy has been made largely on an ad hoc basis in the traditional manner of our society. Now, the growing strength of public opposition to nuclear power would seem to indicate that the technology may well not be accepted unless the 'big issues' are addressed frontally. Improvements will have to be made both in the technology *and* in its regulation if nuclear energy is to be made much more demonstrably safe.

Many such improvements have been suggested in the past—ranging from the underground siting of nuclear reactors to the elimination of their long-lived radioactive wastes by recycling. When these possibilities were suggested originally, the old U. S. Atomic Energy Commission was reluctant to explore them because of the increased costs which they implied and because of the belief that nuclear power was safe enough without them. Now that public acceptance may well have replaced economics as the primary obstacle to the deployment of nuclear energy, it would be wise for the new Nuclear Regulatory Commission to look seriously into some of these proposals.

It will not be possible to improve the safety and environmental compatibility of nuclear power—or any of our other major energy technologies—unless we are able to slow the rate of their deployment to a more measured pace, however. This means that we must reduce the rate of increase of our energy consumption—and that can be done most easily by increasing the efficiency of our energy use. It would be prudent, therefore, as our capital stock turns over, to replace automobiles, industrial equipment, heating plants, appliances, and buildings by more energy efficient systems.

Unfortunately, current federal policy continues to put the emphasis on crash programs for more energy production based on projections of enormous increases in U.S. energy consumption in the near future. Improvements in safety and energy efficiency are still receiving relatively low priorities. Thus, in the Administration's budget for fiscal year 1976, approximately $400 million is proposed for the development of the liquid metal cooled fast breeder reactor (LMFBR) compared with approximately $50 million for safety research on our current generation of light water cooled reactors, and only $3 million for "end use energy conservation research and development."

The next phase of the nuclear debate should put more emphasis on what conditions a fission energy system would have to meet in order to be acceptable. And a much greater emphasis should be put on a campaign for new federal regulations designed to bring about improved energy efficiencies for our important energy consuming systems. In this way it might be possible to buy the time we need to improve the safety and environmental compatibility of all of our energy sources.

These are objectives on which all parties in the nuclear debate ought to be able to agree. ☐

The spread of nuclear weapons—Is the dam about to burst?

Non-Proliferation Treaty in deep trouble as world hovers on brink of a new arms race

THOMAS A. HALSTED

"If we had known in 1968 how little the nuclear powers would do over the next six years to meet their end of the NPT bargain by controlling their arms race, I would have advised my government not to sign the Treaty."

Thus spoke a distinguished former diplomat from a still non-nuclear country at an unofficial conference held last September to discuss issues likely to dominate the May 1975 review conference required by Article VIII of the Treaty on the Non-Proliferation of Nuclear Weapons (the NPT).

The NPT resulted from a consensus between nuclear and non-nuclear countries that the birth of more nuclear powers would lead inevitably to greater risks of nuclear war, and that therefore it would be in the mutual interest of all to devise a regime which would prevent the spread of nuclear weapons without denying anyone the potential peaceful benefits of nuclear energy. Thus the Treaty which was drawn up in 1968 and took effect in 1970 is a compact—between the nuclear powers which committed themselves to end their arms race and work toward nuclear disarmament, and the non-nuclear powers which, in exchange for foregoing acquisition of nuclear weapons, could look forward to reaping the benefits of the peaceful uses of nuclear energy.

Concern about the continued arms race between the nuclear superpowers is only one reason the NPT is in trouble today. Blame for the fragile condition of the Treaty can be laid in many directions:

- First, on the enormous worldwide appetite for nuclear-generated electric power, which brings with it vastly expanded opportunities for the diversion of plutonium and highly enriched uranium from peaceful purposes to the manufacture of weapons, both by irresponsible governments and by nongovernmental terrorist or criminal groups. The worldwide energy crisis has added great momentum to this appetite for nuclear power, while tending to minimize concerns about its attendant risks.
- Second, on the persistent notion that nuclear weapons bring greater security, a delusion held by non-nuclear as well as nuclear powers.
- Third, on exaggerated claims for the potential benefits of nuclear explosions for peaceful purposes.

All of these factors have combined to provide incentives, or at least excuses, for a numerically small but important group of nations to stop short of ratifying the NPT.

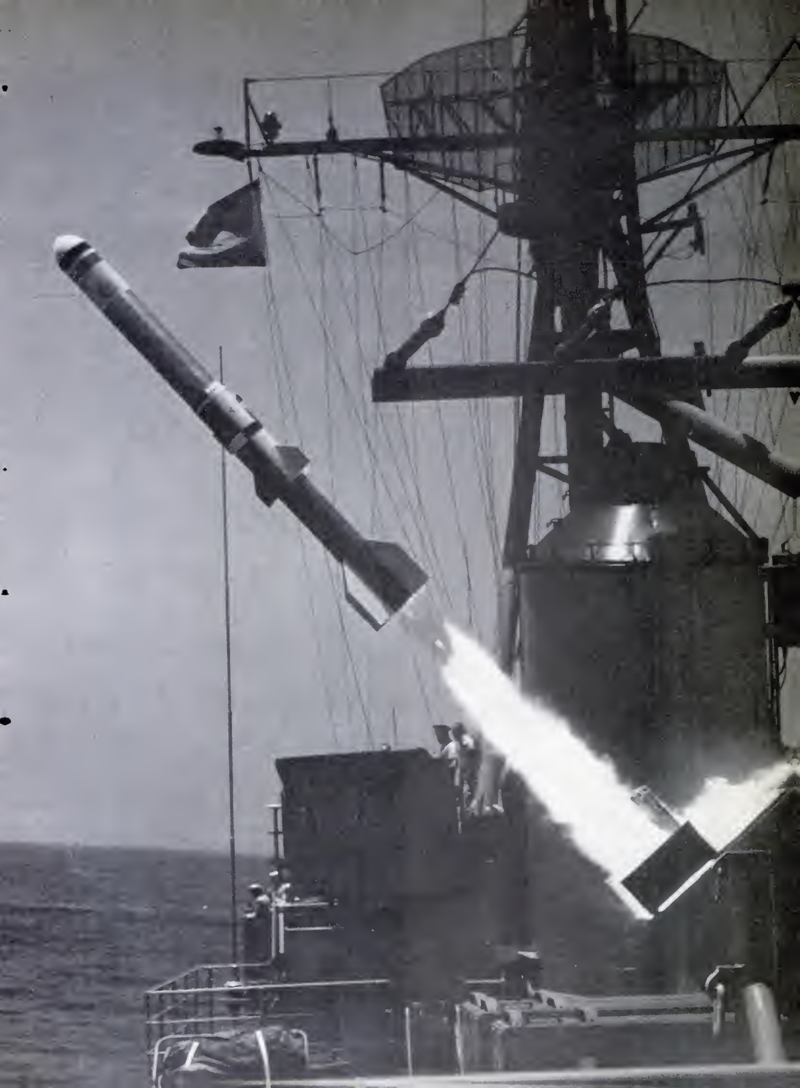
A year ago many observers had reason to believe that the NPT had come of age, and that the review conference was likely to be uneventful. Almost 10 years had passed without the addition of another nuclear power, 83 countries had acceded to the Treaty, and with the apparent resolution of problems that had delayed their acceptance of International Atomic Energy Agency (IAEA) safeguards on peaceful nuclear programs, it appeared only a matter of time before a number of important holdouts (West Germany, Italy, the Benelux countries, and Japan) would complete the ratification process.

This optimism was, unhappily, premature. A series of events which took place over only a few months' span have provided a sharp reminder of the fragility of the NPT regime:

The Indian Nuclear Test. On May 18, 1974, India detonated her first nuclear 'device,' a 15-kiloton explosive set off under the Rajasthan Desert of northwest India. Indian spokesmen insisted to the world that it was for peaceful purposes, and that she would never develop nuclear weapons. The test produced almost universal acclaim in India itself and grave concern and undoubtedly a reappraisal of nuclear options in Pakistan. But elsewhere there was sharp criticism only in Japan, Sweden, and Canada (which had provided the reactors which supplied the nuclear fuel for the Indian test), gen-

Anti-submarine rocket capable of carrying a one-kiloton nuclear warhead catapults from a U.S. destroyer.

Thomas A. Halsted is executive director of the Arms Control Association in Washington, D.C. This article appeared in part in the November 1974 issue of *Arms Control Today* and is reprinted here with their permission.



The Vladivostok agreement to work for a 10-year limitation on strategic offensive arms, rather than reducing the size of each side's arsenals, permits their increase and places almost no qualitative restraints on new weapon developments. It seems to be only an excuse to continue the arms race under new ground rules.

eral approval or at least no criticism from China and the Soviet Union, and only mild clucks of disapproval from the United States.

What political leverage the United States might have exercised to discourage the Indian nuclear program all but evaporated after Secretary Kissinger's visit there in October 1974. In an October 28 speech to the Indian Council on World Affairs in New Delhi, Kissinger seemed to give further official U.S. blessing to India's new status by calling on India to act responsibly in considering the export of nuclear technology. Aside from demonstrating that she could safely run the risk of momentary international disapproval, India gave renewed credibility to arguments in such countries as Argentina and Brazil that peaceful nuclear explosives have a promising future.

The Middle East Reactors. In June 1974 the Nixon administration announced that it had offered to sell Egypt and Israel each a 600-megawatt reactor to produce electric power. The announcement was coupled with the assurance that stringent safeguards would be attached to the sales agreements, probably to include a requirement that the plutonium produced in the reactors would be returned to the United States for reprocessing, to prevent its possible diversion to weapons production.

For the first time since the NPT was signed, a nuclear power, party to the Non-Proliferation Treaty, had undertaken to supply to non-parties equipment capable of producing nuclear weapons materials in significant amounts. The Treaty does not prohibit such transactions, and American defenders of the deals are quick to point out the extra stringency of the safeguards provisions (applied, however, only to the reactors and the materials provided under this transaction, but not to any other nuclear facilities in the recipient countries). Nevertheless, the sales agreements have been strongly criticized, by many who view the infusion of major additions to nuclear technology in the Middle East as extremely dangerous, and by others who see them as not in keeping with the spirit of the NPT, or even as an outright breach of its provisions.

In any event, it is difficult for a non-nuclear party to the NPT not to consider the transactions to be discriminatory if Egypt and Israel, both non-parties, are asked to put only these particular installations under safeguards, while non-nuclear parties to the Treaty must place *all* nuclear facilities under safeguard.

Superpower Summitry. Finally, the arms control agreements last year between the United States and Soviet Union reached in July in Moscow and in November in Vladivostok are regarded as a sham by many non-nuclear powers. The 'threshold' test-ban treaty signed in Moscow in June, allowing both sides to continue testing nuclear weapons underground as large as 150 kilotons (10 times the size of the Hiroshima bomb) after March 31, 1976, and even then permitting the continued testing of 'peaceful' explosives of any size is viewed as a major step backwards.

The Vladivostok agreement to work for a 10-year limitation on strategic offensive arms, rather than reducing the size of each side's arsenals, permits their increase, particularly of MIRV-laden missiles, and places almost no qualitative restraints on new weapon developments. It seems to be only an excuse to continue the arms race under new ground rules.

Taken together, the two events appear to many to be a shabby evasion of the two superpowers' NPT commitments to bring their arms race under control and to "seek the discontinuance of all nuclear test explosions for all time."

In September 1974, the Arms Control Association held a conference in Divonne, France. The events cited above as well as many other factors were considered at length by the 25 participants that were present from countries and several international organizations. They concluded that the NPT, "while far from perfect, is a useful and workable instrument." They felt that performance under the Treaty had suffered more from failure to fully implement its provisions than from weaknesses in the provisions themselves. They made a number of concrete recommendations for action which should be taken to strengthen the Treaty.*

1. The nuclear weapon parties should take seriously their obligations to work toward disarmament, in particular by reducing numbers of nuclear delivery vehicles, limiting further missile flight testing, and negotiating a comprehensive (not a threshold) nuclear test-ban treaty. They viewed the

---

**NPT: Paradoxes and Problems,* the report of the Divonne meeting, can be obtained from the Arms Control Association (11 Dupont Circle, N.W., Washington, D.C. 20036). One to 9 copies are $1.50 each; 10 to 99, $1.00 each; over 100, $0.75 each.

threshold treaty as a "disheartening step backward."

2. To provide better security assurances for non-nuclear powers, nuclear weapons states should pledge themselves not to use or threaten to use nuclear weapons against non-nuclear states party to the Treaty; the establishment of nuclear-free zones should be encouraged.

3. The benefits of peaceful nuclear explosives (PNEs) are questionable. A study should be commissioned by the Secretary General of the United Nations of all the implications of such programs, and it was suggested that meanwhile a moratorium on further PNE tests should be imposed.

4. Henceforth, provisions of nuclear supplies and technology should be made only to those recipients, whether or not parties to NPT, which agree to place *all* their nuclear facilities under IAEA safeguards.

5. Safeguards systems should be strengthened and made universal, with increased attention given to physical security applied to all materials. The problem of diversion of nuclear materials by terrorists, organized criminals and other non-governmental groups should be given immediate attention.

Obstacles and Prospects

Over the long run, implementing these recommendations could provide enough glue to hold the NPT together, but to do so will require overturning major obstacles all along the way.

The United States and the Soviet Union view complaints about their lack of progress at SALT as exaggerated, and clearly think they have bought off objections to their lack of progress in curbing nuclear testing with their dubious threshold test ban. No-first-use agreements have little support from either (although France and China, both non-parties to the NPT, have each offered no-first-use formulations). Nuclear-free-zone proposals are being discussed again at the United Nations, but the only one likely to be in existence for some time is in Latin America—and there are notable holdouts in the case of Cuba, Argentina, and Brazil.

Peaceful nuclear explosions remain a serious stumbling block. The more the nuclear powers discover their uselessness, the more non-nuclear powers declare that the United States and the Soviet Union are looking for excuses to duck their NPT obligations to provide PNE services when the technology becomes available. And India's example has given a powerful new impetus to PNE zealots in other countries considering taking that step.

There is some reason to hope that domestic pressures in the United States will lead this country to adopt a more inclusive sales policy with respect to safeguards, but considerably more thought must be given to safety and security implications as nuclear power installations grow over the coming years in size, number, and geographic distribution. Other potential suppliers of nuclear materials and technology also would do well to consider the long-range security and non-proliferation implications of transactions they might negotiate in the future.

Who will be next?

In May 1974 India became the sixth country to explode a nuclear device, 10 years after China became the fifth, and 29 years after the United States first let the genie out of the bottle. What other nations may be tempted to follow India's example, and become the seventh, eighth, or ninth? How soon? What would a world of 10 or more nuclear powers be like?

The fact that 83 nations have now become parties to the NPT obscures the fact that the list of those which have not includes all the countries which cause concern. These are the countries (in addition to China, France, and India) that have the greatest technical capabilities and political incentives to go nuclear, and the countries which do not find the NPT solves their security concerns.

At least seven countries—all non-parties to the NPT—have or soon will have the technical capacity to build nuclear weapons, and may be under some political pressures to do so. These include:

- **Argentina**
- **Brazil**
- **Egypt (though Egypt has signed the NPT, it is not likely to ratify it until Israel does so)**
- **Israel**
- **Pakistan**
- **South Africa**
- **Spain**

Six other countries clearly have the technical capacity to go nuclear, and have not yet ratified the NPT, but probably have no present incentive to acquire nuclear weapons:

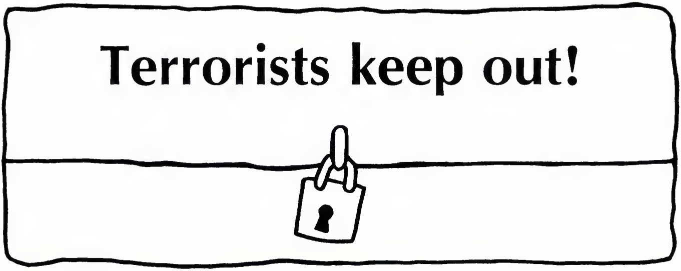
- **Belgium**
- **Federal Republic of Germany**
- **Italy**
- **Japan**
- **Netherlands**
- **Switzerland**

In addition, there are countries now party to the Treaty which might reconsider their support for the NPT and withdraw at any time, after giving the requisite three months' notice, if they were to see new threats to their security.

There was considerable uneasiness, for example, over the recent announcement that France will sell five large reactors to Iran. Although Iran is a party to the NPT and France, though not a party, has repeatedly stated that she would behave exactly as is she were, the size of the deal provoked serious concern. French sales of reactors or other nuclear facilities to a *non-party* in the present atmosphere could have grave implications for the future of the Treaty.

Time is running out. More constructive action must be taken if more countries, disappointed by lack of progress toward disarmament by the nuclear powers, and seeking new ways to enhance their prestige and security, do not soon follow the Indian example. Otherwise the review conference this month may well be more a wake than a celebration. ☐

Terrorists keep out!



The problem of safeguarding nuclear materials in a world of malfunctioning people

MASON WILLRICH

So far in human history two acts of nuclear violence have occurred in war and none in peacetime. The nuclear explosions over Hiroshima and Nagasaki brought World War II to a rapid end and made all too clear the disastrous consequences if mankind failed to prevent this particular kind of violence in the future.

Since the end of World War II, the governments of a slowly increasing number of nations have tested nuclear explosives, and the United States and Soviet Union in particular have each developed and deployed a vast array of strategic nuclear armaments. Yet governments have managed thus far to avoid acts of nuclear violence. It has not been easy. The leaders of the world's most powerful nations have been preoccupied with the dismal subjects of deterrence, crisis management and arms control, while people in all nations have witnessed, as innocent bystanders, a number of close calls with thermonuclear devastation.

There is substantial evidence to indicate that the relatively few governments which presently possess nuclear weapons go to great lengths to avoid their use in acts of violence. There is no evidence, however, to support a conclusion that either governments of nations, or human beings generally, are less prone to violent behavior than they were before the discovery of nuclear fission. In this respect, a number of trends in the field of terrorism appear especially ominous.

As a working definition of terrorism, I mean threats or acts of violence planned, attempted or carried out by an individual or group with a specific political intent in mind. The incidence of violence initiated by various terrorist groups seems to be increasing in many parts of the world. Moreover, terrorist groups are increasing their technical sophistication, as evidenced by the armaments and tactics they use. Terrorist groups are also developing transnational links with each other in order to facilitate the flow among countries of arms, ammunition and personnel. Finally, in an era of almost instantaneous global communications, whatever works as a terrorist tactic in one part of the world is likely to be picked up and possibly emulated elsewhere.

The recent and abrupt end of an era of cheap oil has propelled the world community into the age of nuclear power. The transition from fossil to nuclear fuel to meet future world needs for electric power is already well under way. Over the past two decades, a number of governments have each spent billions

---

Mason Willrich is professor of law at the University of Virginia in Charlottesville. He has served as Assistant General Counsel of the U.S. Arms Control and Disarmament Agency and as a member of the U.S. delegation to the Conferences of the Committee on Disarmament in Geneva and to the Safeguards Review Working Group of the International Atomic Energy Agency. He is the co-author of *Nuclear Theft: Risks and Safeguards*. This article is based in part on an address he presented to the 15th Annual Conference of United Press International Editors and Publishers.

of dollars in nuclear power research and development. Electric utilities and equipment manufacturers in several countries have already invested billions of dollars in operational facilities and additional tens of billions are committed to power plants under construction. Nuclear power is presently the only practical alternative to coal and oil for electric power generation.

In light of the 1973–74 Arab oil embargo, and atmospheric pollution resulting from burning coal with existing technology, the need for an alternative is obvious and urgent. And the economic attractiveness of nuclear power, despite rapid increases in capital costs of power reactors, is assured by the fourfold increase in world oil prices dictated by the Organization of Petroleum Exporting Countries (OPEC) cartel. Thus, despite unresolved issues concerning the operational safety of nuclear power reactors, the environmental and radiological effects of large-scale nuclear industrial operations, and the risks of widespread nuclear weapon proliferation, I believe the trend toward nuclear power is irreversible. The basic issue is not whether we use nuclear power, but how to use it wisely.

Key Facts

How, then, does the development of a worldwide nuclear power industry affect the risk of acts of nuclear violence and the problem of preventing such acts? In order to weigh this question, a few key facts must be born in mind.

First, nuclear explosives are relatively easy to make, assuming the requisite fissionable materials are available. Nuclear explosive devices can be made with a few kilograms of plutonium, high-enriched uranium-235, or uranium-233—a mass of fissionable material about the size of a baseball is enough. The yield of a nuclear explosive device will depend on the quality of the materials used and, most importantly, on the design. The design and fabrication of a simple, transportable, fission explosive is not a technically difficult task.

Second, the effects of a nuclear explosion depend on the characteristics of the device and the target area. A crude, low-yield fission explosive, such as a terrorist group might be capable of constructing, could kill tens of thousands of people and cause hundreds of millions of dollars of property damage in an urban area.

Third, the use of nuclear energy to generate electric power inevitably results in large flows of plutonium, high-enriched uranium, and eventually uranium-233. The light water cooled reactor now in widespread commercial use requires low-enriched uranium fuel, which cannot be used to make a nuclear explosive without further enrichment—a process too complicated and costly for a criminal or terrorist group to perform. However, this type of reactor produces plutonium which could be stolen and used in an explosive after separation at a chemical reprocessing plant and prior to fabrication into fuel for recycling.

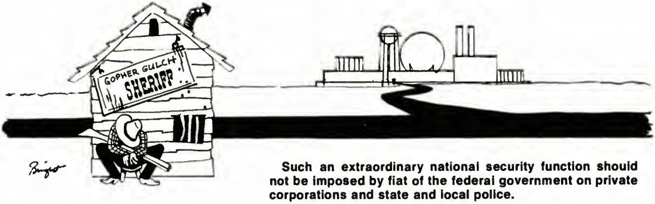
The high temperature gas-cooled reactor now being introduced commercially requires high-enriched uranium fuel which could be used directly in a nuclear explosive, if stolen after the completion of enrichment and prior to completion of fuel fabrication. Moreover, this type of reactor converts thorium into uranium-233 which, like plutonium, could be used in a nuclear explosive after it has been chemically separated from other materials in irradiated fuel.

In the more distant future, and assuming the technology is successfully developed, the sodium-cooled fast breeder reactor will produce more plutonium than it consumes as fuel at the same time that it generates electric power.

In 1974 the Atomic Energy Commission forecasted that in 1980 the U.S. nuclear power industry will use about 19,000 kilograms of materials that could be used directly in nuclear explosives.[1] Worldwide in 1980, nuclear power reactors will be operating in at least 30 countries.[2] Beyond 1980, the number of nations with nuclear power programs will continue to expand and, more importantly, the flows of nuclear explosive materials in countries with large power programs will build up very rapidly.

Where Do We Stand?

Without effective safeguards to prevent nuclear theft or diversion, the development of nuclear power will create substantial risks to the security of nations, the stability of governments and the



Such an extraordinary national security function should not be imposed by fiat of the federal government on private corporations and state and local police.

What is an 'adequate' system of safeguards? And what is an 'acceptable level' of risk of nuclear theft? Such questions should be decided by the public in an open political process.

safety of people in every region of the world. Where then do we stand, in the development of the essential safeguards? A bit of recent history is helpful in answering this question.

The development of safeguards to prevent theft or diversion of strategic materials from the U.S. nuclear power industry was the responsibility of the Atomic Energy Commission until January 1975. Then, in accordance with the Energy Reorganization Act of 1974, the AEC itself underwent fission into the Energy Research and Development Administration (ERDA) and the Nuclear Regulatory Commission (NRC). The details of the division of safeguards responsibility between ERDA and NRC are still being worked out.

The matter is complicated by overlaps between safeguards systems applicable to military or classified programs (ERDA's responsibility) and safeguards applicable to the unclassified parts of the nuclear power industry (NRC's responsibility). It is further complicated by interactions between safeguards related to U.S. agreements for peaceful nuclear cooperation with foreign countries (ERDA's responsibility) and the national safeguards system (NRC's responsibility). A major step forward on the safeguards front was made, however, in the internal structure of the NRC. The Act sets up the Office of Nuclear Material Safety and Safeguards as one of the three principal arms of the NRC's staff—the Office of Nuclear Reactor Regulation and the Office of Nuclear Regulatory Research being the other two.

Until AEC requirements were tightened in December 1973, hundreds of kilograms of plutonium or high-enriched uranium could be stored merely in a locked building that was checked by an unarmed watchman only once every four hours. Moreover, enough plutonium or high-enriched uranium for tens of nuclear explosive devices could be shipped across the country simply in an unescorted truck driven by a single, unarmed driver who was not in continuous communication with anyone. These and other glaring defects in AEC safeguard requirements and the prevailing lax attitude within the nuclear industry toward the nuclear theft problem were highlighted in a report by the General Accounting Office to the Congress in November 1973.[3] Thereafter, some of the defects were remedied by regulatory changes.

In early April 1974 a study of safeguards against nuclear theft, co-authored by Theodore B. Taylor and myself, was released by the Ford Foundation's Energy Policy Project.[4] During the course of our year of research it became clear to us that the U.S. government had examined this problem only superficially and sporadically, and that much of the nuclear industry was largely unaware of the seriousness of the risks involved.

One broad conclusion of our study was that "a system of safeguards can be developed that will keep the risks of theft of nuclear weapon materials from the nuclear power industry at very low levels." Such a system would require use of the best available technology and institutional mechanisms. That was the good news. The bad news, however, was that the AEC's current system of safeguards, including the strengthened requirements, was far from adequate. Taken together, the aggregate of existing safeguard requirements do not constitute a system, or a systematic approach, to the problem of preventing nuclear theft.

Prior to publication and release, our study was subjected to an extensive and intensive review process, including comment from the AEC, which we as authors found very helpful. With our draft available, the AEC commissioned a special safeguards study of its own. This was performed by a group headed by an AEC staff member and included a nuclear materials production expert, a nuclear weapons specialist, a nuclear physicist and a former assistant director of the F.B.I. A copy of this in-house study, known as the Rosenbaum report, was pried loose and released by Senator Ribicoff in late April 1974.[5]

The AEC report foresaw the frightening possibility of a rise in "urban terrorist groups in this country. . .likely to have available to them the sort of technical knowledge needed to use the now widely disseminated instructions for processing fissile materials and for building a nuclear weapon. They are also liable to be able to carry out reasonably sophisticated attacks on installations and transportation." The AEC report minced no words in its conclusions: "that the new regulations are inadequate and that immediate steps should be taken to greatly strengthen the protection of special nuclear materials."

Since the publication of the Energy Policy Project safeguards study and the strong confirmation given our findings by the AEC's internal study of the same matter, the Commission's staff issued in August 1974, a four volume draft environmental impact statement, as required under the National Environmental Policy Act, in order to provide a basis for deciding whether and on what conditions to permit the recycle of plutonium as fuel in light water reactors.[6] As an indication of the economic significance of this decision, the energy contained in the plutonium that would be recycled in U.S. power reactors through 1995 is estimated to be equivalent to 10 billion barrels of oil or 2 billion tons of coal.

With respect to safeguards considerations, the AEC's conclusion is that its current requirements will not be adequate. However, the AEC also concludes that if a number of major new concepts are implemented, and if decisions on upgrading the system are taken within about one year after the final impact statement, then the safeguards problem will be "manageable." Hence, if a major upgrading of safeguards does not occur within such a time frame, the risks of nuclear theft and sabotage may, according to the AEC's own analysis, prove to be unmanageable.

In 1974, therefore, the AEC staff appeared to have undergone a major change of attitude toward the safeguards problem. In addition, there has been a growing appreciation among a few members of Congress of the seriousness of the danger and the high stakes involved.

Despite this progress, our nuclear safeguards program remains in danger of being starved to death for lack of funds. Prodded by outside criticism and pushed by the results of its own rethinking, the AEC requested an additional $85 million to upgrade its safeguards effort during Fiscal Year 1975. Of this amount, 80 percent was slashed by the Office of Management and Budget—including the entire amount requested to beef up the AEC's (now the NRC's) regulatory staff in this area. A small portion of the cut was restored by last minute action in the Joint Committee on Atomic Energy.

Our nation's economic difficulties do not justify gambling with the safety of the American people and the security of our governmental institutions from nuclear threats. Therefore, it is to be hoped that adequate funding levels for stronger safeguards will be provided in the Fiscal Year 1976 budgets of ERDA and NRC, which are now under consideration by the Congress. Perhaps more important at this stage than money is a heightened sense of awareness of the safeguards problem and the large stakes in the world's energy future in finding effective and practical solutions. Such an awareness still needs to be instilled at the top levels of government and industry in order that lower levels can do their jobs.

The costs of an effective system of safeguards against nuclear theft would be only a very small fraction of the value of electricity produced with nuclear fuel. Yet the costs of an ineffective system would be immense, not only for the American people but for the entire world community.

Effective safeguards against nuclear theft or sabotage in the United States is only part of a much larger global problem. In order to come to grips with the international issues, however, we must have our own house in order.

Little is publicly known about the efforts in other countries with nuclear power programs to develop and implement their own safeguards to protect against nuclear theft. Yet terrorist organizations are even more of a threat in several of these countries than in the United States. The risk of nuclear theft affects us all since plutonium or high-enriched uranium stolen from the U.S. nuclear power industry could be used in a terrorist attack in some other country, and material stolen in another country could be used by terrorists to hold hostage a city in America.

At International Level

Almost no serious discussion of this problem has occurred at the international level, though there have been a few preliminary technical efforts. The time that national political and industrial leaders have to deal with the problem is rapidly running out, and leadership in this area appears so far to be lacking.

India's detonation of a nuclear explosive using plutonium produced in a reactor obtained from Canada under a 'peaceful uses' guarantee was a substantial setback to international efforts to curb the proliferation of nuclear weapons among governments through the Non-Proliferation Treaty. Regardless of their attitudes toward the acquisition of nuclear explosives by more and more governments, all governments have a common interest in preventing nuclear theft from their own nuclear industries and also from the industries of other countries.

Systems of national safeguards can be developed that will keep the risks of theft of materials for nuclear explosives from nuclear power industries at very low levels. Of course 'zero risk' is an impossibility in this, as in other, dangerous human activities. Yet clearly adequate safeguards should be a condition for the continued development and use of nuclear power. But such statements beg the important questions: What is an 'adequate' system of safeguards? And what is an 'acceptable level' of risk of nuclear theft? These are central political issues that should not be decided in our society by any group of experts, no matter how informed or well intentioned, within government or industry. Such decisions should be made, reviewed, and remade through the pulls and tugs of widely divergent views expressed forcefully, but fairly, in an open political process as nuclear power develops and the social context changes. At the same time, widely differing safeguards positions may be taken by other governments, many of which are based on far different principles from ours. And their domestic safeguards decisions will necessarily affect our security too.

The following summarizes my current thinking concerning the major directions toward which the U.S. safeguards program should be headed in the immediate future in order to provide the American people with adequate safeguards against nuclear theft. The new NRC is already moving, or is seriously considering moving, in these directions, but it still needs encouragement and more sup-

Copyrighted material

A human problem for which there is no technological fix.

port. The need is especially great at this time for active support and leadership on safeguards issues to come from within the nuclear industry itself. After all, private industry's economic interests would be seriously jeopardized by a successful large nuclear theft.

Safeguards should emphasize the *prevention* of theft and the detection of any theft attempt in time to prevent its completion. Detection of a completed theft, recovery of stolen material, and response to any nuclear threat involving stolen material are important supplementary safeguard functions. The physical barriers and security forces employed should be capable of defeating the maximum credible threat that can be reasonably expected. Within the United States, such a threat might involve an attack by a group of perhaps 10 to 15 persons using sophisticated firearms and equipment. Insofar as practical, instruments and techniques should be developed and used to provide a timely and accurate picture of the material flows in the various nuclear fuel cycles, and to detect immediately the flow of any nuclear explosive materials out of a material access area through an unauthorized channel. After-the-fact accounting methods will be insufficient in view of the quantities of materials involved and the short response time available.

Co-location of nuclear fuel cycle support facilities—enrichment, fuel fabrication and chemical reprocessing—could virtually eliminate the transportation links that are most vulnerable to nuclear theft. In this connection, the Energy Reorganization Act requires the new NRC to undertake a national nuclear energy center site survey.

Furthermore, the possibility of 'spiking' plutonium used in the nuclear power industry that is, leaving sufficient fission products in plutonium that is reprocessed to constitute a lethal hazard to anyone who handles it without massive shielding—should also be seriously considered. Such spiking might reduce the cost of reprocessing, reduce the long-lived radionuclides in radioactive wastes, increase the cost of shipping (if fuel cycle facilities were not co-located), and increase the costs of fuel fabrication. Of course, an advantage of co-location of fuel cycle facilities is that it would reduce the need for measures such as spiking.

Under the existing safeguards approach, each operator of a nuclear facility is responsible for providing a private security force, intended to work in cooperation with local police, to protect nuclear explosive materials at the facility and during transportation. I do not believe such an extraordinary national security function should be imposed by fiat of the federal government on private corporations and state and local police. The private nuclear industry is in the midst of a demanding technological innovation under difficult economic circumstances. Local law enforcement authorities are already overworked, underpaid, and sometimes unable to cope with the present level of conventional violence in society. Despite serious philosophical and practical reservations regarding any real or apparent move in the direction of a police state, I believe we should seriously consider the establishment of a nuclear materials security service as a direct responsibility of the federal government.

Finally, the U.S. government should, as a matter of urgency, pursue discussions with other governments with substantial nuclear power programs in order to develop a common policy concerning safeguards against theft. In 1972, the International Atomic Energy Agency convened a panel of experts which developed recommendations for the physical protection of nuclear material, and the IAEA has since then sponsored some further technical discussions. In 1974 Secretary Kissinger proposed before the United Nations that a treaty be negotiated to provide international standards for physical security of nuclear materials. There will be an opportunity to discuss this subject at the Non-Proliferation Treaty review conference which is convening this month in Geneva. International diplomacy must be speeded up and intensified if adequate safeguards against nuclear theft are to be applied to the burgeoning worldwide nuclear power industry.

In conclusion, emergency core-cooling systems and other safety features built into nuclear power reactors are designed to deal with the risk of malfunctioning machines. Safeguards against nuclear theft and sabotage are intended to deal with the risk of malfunctioning humans. The possibility of nuclear violence using material diverted from civilian industry is fundamentally a human problem for which there is no technological fix. There is no final solution. Nor is there any alternative to dealing with it effectively until the last fissionable atom has been split.

NOTES

1. AEC, Office of Planning and Policy Analysis, *1974 Forecast*, WASH-1139 (Washington, D.C.: The Commission, 1974).

2. Listed in order of the size of their projected installed nuclear power capacities in 1980 these countries are: United States, Japan, West Germany, United Kingdom, Soviet Union, Sweden, France, South Africa, Canada, Switzerland, Taiwan, Korea, Italy, East Germany, Czechoslovakia, Belgium, India, Argentina, Finland, Mexico, Netherlands, Spain, Romania, Bulgaria, Austria, Brazil, Yugoslavia, Thailand, Philippines, Pakistan.

3. Comptroller General of the United States, *Improvements Needed in the Program for the Protection of Special Nuclear Material*, Report to the Congress (Washington, D.C.: GAO, Nov. 7, 1973).

4. Mason Willrich and Theodore B. Taylor, *Nuclear Theft: Risks and Safeguards* (Cambridge, Mass.: Ballinger Publishing Co., 1974).

5. D. M. Rosenbaum, J. N. Googin, R. M. Jefferson, D. J. Kleitman, and W. C. Sullivan, *Special Safeguards Study*. Excerpts appeared in the Congressional Record, April 30, 1974, p. S6621.

6. AEC, Director of Materials Licensing, Fuels and Materials, *Draft Generic Environmental Statement Mixed-Oxide Fuel*, WASH-1327 (Washington, D.C.: The Commission, Aug. 1974).

The special case of chemical and biological weapons

Without a breakthrough in disarmament talks, they could be assimilated into world arsenals

J. P. PERRY ROBINSON

The joint U.S.-Soviet communique from Moscow dated July 3, 1974, contains the following passage:

> Both sides reaffirmed their interest in an effective international agreement which would exclude from the arsenals of states such dangerous instruments of mass destruction as chemical weapons. Desiring to contribute to early progress in this direction, the USA and the USSR agreed to consider a joint initiative in the Conference of the Committee on Disarmament with respect to the conclusion, as a first step, of an international convention dealing with the most dangerous, lethal means of chemical warfare.

The reference to a "joint initiative" in the Conference of the Committee on Disarmament (CCD) might possibly be interpreted as a step forward when set against the corresponding passage in the U.S.-Soviet communique of June 25, 1973:

Julian Perry Robinson, chemist, is a research fellow of the Science Policy Research Unit and of the Institute for the Study of International Organizations at the University of Sussex, England.

If weapons work, they will be used. Despite initial repugnance, the crossbow, gunpowder, flame-throwers and napalm all eventually became part of conventional warfare.

> Considering the important role which an effective international agreement with respect to chemical weapons would play, the two sides agree to continue their efforts to conclude such an agreement in cooperation with other countries.

But, in fact, the grounds for optimism are not strong. It is disturbing to learn, for example, of superpower agreement on a stepwise approach to the problem—on confining the "first step" to "the most dangerous, lethal" chemicals. And then there is the fact that the decision to go for any sort of chemical treaty was still pending in Washington (and probably still is), whatever the communique may have suggested to the contrary. To the extent that the consequence of this may be an undercutting of the Defense Department's stance in the U.S. National Security Council's consideration of the matter, there are grounds for optimism. But to the extent that the communique may be public-relations rhetoric, substituting for any real superpower interest in multilateral armaments limitation, there are also grounds for pessimism.

The fact of the matter is that when the National Security Council review of chemical weapons policy got under way earlier this year, the odds were heavily weighted against a policy outcome that favored any immediate, significant step further toward chemical disarmament. The best that could be hoped for was a decision against foreclosure on the disarmament option and against endorsement of the Army's plans to embark upon a new round of chemical weapons buying. This would allow time, hopefully, for the pro-disarmament faction in Washington, such as it is, to increase its strength, and for the Socialist countries in the CCD to formulate a more defensible position on the question of international verification. All in all, therefore, the prospects for rapid progress on chemical weapons at the CCD do not look bright.

Against this background it is useful to consider the long-term implications of a failure to reach an agreement on chemical weapons and, the opposite side of the same coin, the goals that should be established as the long-term objectives of a chemical disarmament agreement.

Elsewhere I have argued that the primary function of a chemical disarmament agreement should be to constrain proliferation.[1] I take the view that the threat to international security which would arise from nerve gas proliferation would greatly exceed the threat which is currently thought to exist in those few areas of the world where nerve gas weapons are at present deployed. In a paper I presented to the 1974 Pugwash chemical warfare workshop, I explored certain of the conceivable determinants of chemical proliferation, and here I seek to define and analyze one of these determinants, namely the process of assimilation.[2]

Many, very different, modes of combat come within the category of chemical and biological warfare (CBW). Its scope is large because toxic and infective agents have potential applications throughout the entire spectrum of armed conflict—from global war to sabotage or terrorist activities of dissident groups. Yet, the same is true for most other agents of warfare at the disposal of armed forces: explosives, bullets, flame, etc. And just as these agents are likely to be used in conjunction with one another, the CBW agents are unlikely to be used in isolation from them. What justification then is there for making a special category out of CBW and treating CBW as a special case in disarmament negotiations?

The justification is to be found in the attitude of the military themselves. There do not appear to be any countries whose military do not treat CBW as a more or less special case. To varying degrees around the world, CBW has its own separate organizations, institutions, logistical procedures, training programs, and so forth. In few, if any, countries can these be said to be fully integrated into their background. Where CBW instruction is included in the basic curriculum of recruits, the training is rarely extensive and is generally limited to the elements of protective countermeasures. In the very few countries where offensive CBW training is given, it is for the most part limited to special cadres. CBW thus lies outside the mainstream of military theory and practice.

Military interest, as regards armaments, has always centered on explosives, projectiles, and other means of physical destruction. Until such time as the principles and technology of CBW have become more fully assimilated, CB weapons will remain 'unconventional.' The process of assimilation is the process whereby novel, unconventional weapons eventually become accepted as 'conventional' weapons.

Isolated as they are within a distinctly outcast category, CB weapons have acquired an array of moral and legal proscriptions that is unique among present-day armaments. This, however, is something with which most novel weapon technologies of the past have had to contend. Users of the cross-

First we'll get a mop, and pick up the broken glass. Then, just to be on the safe side, we'll have this whole section of the country evacuated.

bow, for example, in twelfth century Europe risked excommunication by the Church, and gunpowder went through a long period of moral opprobrium before becoming assimilated. People eventually became accustomed to these developments, and the weapons became conventional.

Incendiary weapons provide a further example: witness the obloquy that fastened upon the recorded users of Greek fire in medieval Europe, or General Beauregarde's expressions of moral outrage during the American Civil War, or the special attention given to flamethrowers in the League of Nations disarmament deliberations, and then the increasing conventionalization of napalm and other incendiaries during the Spanish Civil War, World War II, the Korean war and Vietnam.

CB weapons have been used sporadically for at least 3,000 years, so what is it that has impeded their assimilation? References to them—few and far between, it must be said—occur throughout the recorded history and literature of many civilizations, including the Epic and Vedic Indian, the Hellenic, the Roman, the Byzantine, the Sung Chinese, and that of medieval and Renaissance Europe. The information available does not permit an assessment of the military significance of these early instances. It seems reasonable, however, to suppose that CBW could not compete seriously with other forms of warfare until the prevailing accomplishments of technology had reached an advanced level.

The efficacious use of CBW agents under combat conditions is not easy, and requires rather sophisticated equipment. Advancing further with this hypothesis, one may identify the point at which CBW acquired importance with the great influx of science and scientists into the military world at the time of World War I. It is certainly the case that much of present-day CBW theory derives from the practical experience of chemical warfare during that war.

The French were the first to use chemical weapons during World War I, but it was Germany that made the crucial technical innovation. Among the belligerents, at the outbreak of hostilities, Germany alone had access to the necessary technology (in particular, an industrial capacity for large-scale liquefaction of chlorine gas). Germany turned to chemical warfare in 1915 as a possible way out of the trench warfare stranglehold and in the face of an acute shortage of the nitrates needed for explosives manufacture. The other major belligerents soon caught up, however, and by the end of the war had far exceeded the scale on which Germany was capable of conducting chemical warfare. There were in all between one and two million CW casualties.

CBW Techniques

There are three principal ways of securing battlefield casualties with CBW agents: parenteral injection, contamination of food or drink, or bulk dissemination. The earliest recorded CB weapons worked either by parenteral injection, as in the case of poisoned arrows, or through contamination of food or drink. In the third method, bulk dissemination, the agent is used to pollute the air breathed by the enemy or to contaminate the ground over which he moves, thus creating a hazard to the skin.

Liquefied chlorine gas, and its subsequent developments, enabled bulk dissemination to be exploited on a scale that had never before been approached by any of the other methods. The cylinders of liquid chlorine, releasing a dense cloud of gas when they are opened, permitted an unprecedentedly high level of toxic air pollution, one which could be localized with a fair degree of precision over enemy postions. Much, of course, depended upon the prevailing weather conditions, particularly wind direction, but as artillery techniques developed, so also did the possibilities of using agent-filled projectiles to compensate for unfavorable weather.

Bulk dissemination remains the most important of the three offensive CBW techniques. The other two are limited essentially to sabotage and assassination, although recent technological advances may have broadened the applications of the parenteral one (notably the possibilities for using infected mosquitos or other such disease vectors to spread germs, and for using deliberately contaminated shrapnel or multiple-flechette—'beehive'—munitions, as in the now defunct DIACBA development program of the U.S. Army).*

From an operational point of view, however, there are many practical difficulties and unpredictabilities associated with bulk dissemination. These speedily became apparent during World War I. And these problems exist even today, despite intensive endeavors in the weapons laboratories to mitigate them. They constitute one of the major discouragements of CBW, and may be identified as a principal constraint on the fuller assimilation of CB weapons.

Technological Constraint

This constraint is essentially a technological one and, therefore, sensitive to technological progress. It has several components. One has been alluded to already, namely weather dependence. Quite a small change in weather conditions can necessitate a ten- or even a hundredfold increase in the number of CB munitions needed for a particular mission. Or, conversely, it may vastly increase the hazard downwind of the target area, thereby endangering friendly personnel or noncombatants, even in the distant neighborhood. The allowances that must be made for this will gravely complicate logistical and operational planning.

A second element in the constraint arises from the protective countermeasures that are available against bulk dissemination: respirators, protective clothing, automatic alarms, and so forth. Modern versions of these are capable of providing a rather high level of defense against CBW attack. The significant point, however, is not that protection is available, but rather that, under combat conditions, there will be great uncertainty: first, about how well the enemy is in fact protected; second, about the extent to which that protection impairs his overall fighting efficiency; third, about the degree to which the stresses and strains of combat will have opened gaps in the protection. Damage, haste and poor discipline will inevitably combine to make even the best-prepared defensive posture vulnerable to a CBW attack that is sufficiently heavy; but the attacker will not be able to predict his results with any confidence. The one exception to this is, of course, in the case where the enemy is known to lack any form of protective capacity whatsoever. It is a significant fact that all the major instances of antipersonnel CW since World War I—in Ethiopia during 1935–36, in China during 1937–45, in the Yemen during 1963–67, and in Indo-China since 1964—were initiated against an enemy incapable of deploying antichemical protection.

A third element in the technological constraint is time dependence. With the sole exception of the sensory irritants, no CBW agent produces an immediate effect. In addition, CBW agents can remain active and dangerous in the environment for a period of anything between minutes and years. Although this may be an advantage for certain specialized types of military operations, the complexities which it will introduce into forward planning may be very great. The effects of bulk dissemination of CB weapons are thus poorly controllable, not only in space but also in time.

The importance of the technical factors outlined above cannot be overemphasized, for it is on them that the likelihood of future CBW critically depends. The technological constraint, in conjunction with the psychological one noted below, provides a plausible explanation for the humble status of CBW in military circles today. But both constraints are vulnerable to change. It is possible to envisage a weakening of the inhibitions about CBW and a concentration of technological resources into the development of CB weapons that are militarily and politically more amenable than those available at present. This is what has been happening over the past 30 years in the case of napalm and other incendiary weapons.

Incentives for Assimilation

The incentives that might promote the assimilation of CB weapons can also be categorized as technological and psychological. As regards the latter, CB weapons are pre-eminently weapons of terror. Man's fear of poison and disease appears, on historical evidence alone, to be extremely deep-rooted so that exposure to CBW agents, or the threat of exposure, may elicit very powerful responses. A potential user of CB weapons might well suppose that these responses would act in his favor. He might even value them as an instrument of strategic blackmail or deterrence. The notion of CB weapons

---

*No explanation of the acronym DIACBA is officially available as it is considered classified information. Unofficially, however, according to one authority, it is an acronym for 'Direct-injection ammo for chemical or biological agents.' Ed.

The record of international law in restraining wartime behavior is not impressive; the law has more often been the servant, not the master, of military expediency.

as 'the poor man's atom bomb,' particularly biological weapons, has been around for many years.

The technological incentives remain much as they were during World War I, with certain additions. Bulk dissemination of CBW agents provides a means for attacking large area targets; and airborne CBW agents can penetrate into spaces protected against physical attack. These are factors of some moment today, for the great weight of tactical firepower—nuclear and non-nuclear—now available has imposed doctrines of dispersed deployment in which ground forces are scattered over wide areas. On a weight-for-weight comparison, CBW agents could be considerably more potent than almost all military casualty agents, even fissionable materials. This suggests CBW agents could compensate for quantitative manpower inferiorities. The 'biospecific' character of CB weapons, namely their capacity for leaving inanimate objects largely intact, has certain obvious attractions both at a tactical and at a strategic level. And the recent emergence of incapacitating CBW agents, ones that cause predominantly nonfatal battle casualties, could provide a means for lessening some of the political costs of using armed force—a consideration which, on the civil front, leads police forces to use tear gas. The development of antiplant and, to a lesser extent, antianimal CB weapons adds a further dimension.

Psychological Constraint

It is conceivable that if rigorous analyses were made of all the technological constraints and incentives that would govern resort to CBW in particular war scenarios, with full regard paid to the capabilities of existing CBW technology, offensive and defensive, the balance of judgment might, in some scenarios, favor use of CB weapons. This is certainly something which the advocates of CB weapons have long claimed, not least before U.S. congressional appropriations committees. The details of the analyses have, however, usually been shielded from general scrutiny by security-clearance requirements. If, nonetheless, it is assumed that the analyses have been adequately founded and their conclusions reasonable, the question still remains as to why past advocacies of CB weapons have not been more successful. What other reasons are there for the relatively low level of military interest in CBW, and could they change with time?

The factors that seem to be at work here may be thought of as the psychological constraint. Whether in fact a psychological explanation for them is to be preferred over, say, a behavioral or a sociological one is a matter for further study. The most obvious expression of the psychological constraint is seen in the attitude that CBW is in some way dishonorable, impugning military codes of professional behavior, an attitude that still seems to be widespread in military circles. A second expression of this type of constraint is seen in the legal proscriptions that are associated with CBW. Since its earliest days, the use of CB weapons has been considered peculiarly reprehensible, a view that was embodied in Roman and in Islamic law, and which is retained in a more explicit form in the modern international law of armed conflict. The central element in the present-day legal proscription is the Geneva Protocol of 1925, an international treaty to which most states are parties. The Protocol outlaws use of CB weapons, but has nothing to say about their possession.

International law is closely bound up with public opinion, which it serves both to define and to direct. When opinion changes the law begins to weaken, but opinion on CBW seems to be as hostile as ever, despite recurrent attempts at modifying it. In the short term, these attempts have sometimes succeeded (as when the U.S. Army Chemical Warfare Service succeeded in blocking U.S. ratification of the Geneva Protocol in 1926), but opinion on CBW has always tended to revert to its former state. Considered on purely logical grounds, there is no convincing reason why CBW should be regarded as any less acceptable, or more acceptable, than other forms of warfare. There is undoubtedly an element of paradox in the degree of attention it has received from jurists. To say this is not to call into question their wisdom; rather, the irrationality of the situation, and its persistence in the face of rationalizing attempts by CBW advocates, indicates the strength of the underlying psychological and sociological factors.

Law of Armed Conflict

The record of international law in restraining wartime behavior is not impressive; the law has more often been the servant, not the master, of military expediency. In the case of CBW, however, the relevant law will remain a substantial restraint at least for as long as the appurtenances of CBW remain poorly assimilated by the military. More important, the law constitutes an obstacle against further assimilation.

Conversely, erosion of the law on CBW will facilitate assimilation. That is why the controversy regarding the legal status of herbicides and the sensory irritant agents, such as CS and the tear gases,

The Vietnam war provided a much needed opportunity for the Chemical Corps to demonstrate the value of its wares to the U.S. Army.

has been so important. Largely as a result of their employment by the United States and allied forces in Indo-China, and subsequently by their adversaries, CS weapons are now the furthest advanced toward assimilation of all CB weapons. But the Vietnam-related efforts to reduce, through R&D, the technical and operational limitations of CS weapons, and to increase their military utility and attractions for regular combat forces, has inevitably meant a weakening of at least the technological constraint on the assimilation of all types of CB weapons. This, it should be noted, was by no means an unintended consequence of the use of CS, and herbicides as well, in Vietnam.

During an interview, the U.S. Army Chief Chemical Officer was utterly explicit on this point: the Vietnam war provided a much needed opportunity for him to demonstrate the value of his wares to the Army at large, and for the Chemical Corps to secure that combat role which would enhance its status and protect it from bureaucratic repression in Washington. CS employment, chemical crop destruction and chemical defoliation were only three of many CBW proposals put forward by the Chemical Corps for the Vietnam war.

The Geneva Protocol of 1925 is the strongest available bastion against this particular process of assimilation. The fact that the United States has finally ratified it is therefore an event of the greatest importance, but it is exceedingly unfortunate that the Administration should have persisted in its view, against the advice of its jurists, that the Protocol does not cover herbicides and irritants. The Senate Foreign Relations Committee succeeded in bringing the Joint Chiefs of Staff to a compromise in the form of accepting as national policy certain restrictions on the first use of these agents. But there is a disturbing similarity between the way the restrictions are worded (no first use of irritants "except in defensive military modes to save lives") and the Pentagon's public statements about CS employment during the height of its Vietnam involvement. It is to be hoped that the Committee's further success in extracting from the Administration detailed clarifications for the public record will indeed constrain the military from future excesses. The Army's development program for its newest chemical irritant—the cycloheptatriene derivative known as EA 4923—will be watched with concern.

There is another locus of potential erosion. Since 1970, it has been the British government's position that although tear gases are covered by the Protocol, "CS and other such gases" are not. The decision to adopt this bizarre interpretation arose out of the exigencies of the situation in Northern Ireland (where CS weapons were being used), even though the Protocol is not applicable there. But since 1972, the British Army has been stockpiling weapons based on the newer, and more potent, agent CR (dibenz[*b,f*][1,4]oxazepine). The effects of CR are longer lasting than those of CS, and fall within the current U.S. definition of an incapacitating agent.

Whatever the present U.S. position may be on agent CS it does at least foreswear the first use in war of incapacitating agents. Yet, because in the British Defence Ministry's view CR is evidently subsumed within "CS and other such gases," the British government is apparently reserving the right, unless it withdraws its 1970 interpretation of the Protocol, to use incapacitating agents in war as well as the irritant agent CS.

Assimilation and CB Disarmament

In 1972, after nearly four years of talks on CBW at the Conference of the Committee on Disarmament (CCD), the Biological Weapons Convention was opened for signature. It contains a commitment to negotiate further, and in good faith, for the elimination of chemical weapons. The fact that biological weapons were separated out from the CB weapons category can be understood in terms of assimilation. The practice of biological warfare is technologically more demanding than that of chemical warfare, and psychologically more disquieting.

Biological warfare agents have characteristics which are difficult to harness for offensive purposes, and which do not fit at all easily into military practice. In the case of the United States, biological weapons were the subject of an R&D program which became quite intense during the early 1960s. But, even so, not one device ever passed through acceptance trials by the U.S. Air Force, the potential user for whom they were least unsuited. The weapons seem to have come up against major technical problems, which there was no great incentive to have solved. The stockpiles and the production facilities of BW agents that were destroyed several years ago were in support of a development program that had already become moribund. Chemical weapons, in contrast, were less poorly assimilated, but the United States (and maybe other countries too) is not yet willing to forego their possession.

The suggestion here is that it is the extent to which a particular class of weapon has become assimilated which determines the prospects for its elimination via a partial disarmament agreement. The agreements on collateral measures which have been concluded so far would seem to bear this out, for they are directed against activities which the military has no particular wish to indulge in. Dispiriting though this conclusion may be, it has a practical corollary: the long-term stability of a disarmament agreement will be determined by the extent to which it brings under control the pressures toward further assimilation.

Research and development activities are an obvious source of pressure in the case of chemical weapons. There are two particular areas of concern, neither of which have yet received the attention they deserve from the CCD.

The first is that of incapacitating agent research, because it is these agents that most threaten the psychological constraint on assimilation. Until rather recently the problem did not seem to have all that much urgency, largely because of the difficulties which the R&D teams concerned were likely to have in coming up with a militarily attractive agent. The importance which the U.S. Army attached in the early 1960s to the psychochemicals SN and BZ was soon shown to be unfounded; and the inclusion of toxins within the Presidential renunciations of 1969/70 precluded the further development of PG, a staphylococcal enterotoxin formulation. But it now seems that the U.S. Army has found a new and more attractive candidate, a percutaneously-active anticholinergic glycolate code-named EA-3834. This new psychochemical, whose specific attractions remain classified, and munitions for it, are now in the terminal stages of development.

The second area of concern is that of R&D on chemical warfare protection. Since it is unlikely, and probably undesirable, that a chemical agreement could ever be negotiated that proscribed anti-chemical countermeasures, the supporting R&D will presumably continue. Yet it is precisely from this type of work that several of the major developments in offensive CW techniques have in the past originated.

Military Doctrine

Since use of chemical weapons is illegal, their continued stockpiling seems to imply a scant regard for the provisions of international law. But the laws of war derive what strength they have from the sanction of reprisal, so that as a retaliatory capability the stockpiles can be given a sort of justification. The fact that they are also available for initiation of CW, law or no law, is no doubt seen as an advantage by those who value a wide range of military options. It is seen as a disadvantage, and a reason for pursuing chemical disarmament, by those who see in this ambivalence a source of international mistrust and tension.

Clearly there are parallels to be drawn here with nuclear weapons, but they should not be taken too far. States that possess nuclear weapons have by now been forced to condition themselves into at least some degree of readiness to use the weapons. So, with greater or lesser reluctance, nuclear weapons have been accepted into military doctrine and the doctrine has been modified to accommodate them. Such is not yet the case with CB weapons. There is a school of thought among strategists which holds that CBW has an important role to play as an intermediate rung on the ladder of escalation, providing a firebreak option between conventional and nuclear war. But this is a precarious rationale, for the more rungs there are, the easier will the ladder be to climb. Current British policy, for example, appears to envisage nuclear retaliation against CBW attack.

New weapon technologies have a momentum of their own.

What also has to be kept in mind is the strong element of ex post facto rationalization that runs through much of military policy-making, both nuclear and non-nuclear. One of the effects of mobilizing science and technology in the service of national defense is that new weapons tend to appear before there is any obvious requirement for them. The technologies concerned have a momentum of their own, and so long as a thriving military technology is valued as an element of national security, military policy and doctrine must be elastic enough to accommodate it. This does not seem to have been an easy task in the case of CB weapons technology, which, at least in the United States, has long been outstripping military requirements; and the military authorities concerned, as distinct from the CBW advocates, have so far shown little enthusiasm for attempting it. When they have been forced to articulate a reasoned CB weapons policy, the doctrine of like-with-like deterrence has, for all its obvious shortcomings, been put forward. Time could well bring with it a very different attitude, if CB disarmament does not come about first. It is entirely conceivable that the march of progress within the R&D laboratories, and a loosening of the inhibitions about chemical and biological warfare, could promote wider assimilation of CB weapons and ultimately their acceptance as conventional weapons.

NOTES

1. J. P. Perry Robinson, Statement to Subcommittee on National Security Policy and Scientific Developments of the Committee on Foreign Affairs, U.S. House of Representatives, May 2, 1974. (The hearings of the Subcommittee have been published under the title *U.S. Chemical Warfare Policy.*)

2. Robinson, "Binary Nerve Gas Weapons," paper presented to Pugwash Chemical Weapons Workshop, Helsinki, Feb. 1974; see, especially, pp. 39–42.

This paper, revised and updated, has now been published under the title "The United States Binary Nerve-Gas Programme: National and International Implications," ISIO Monograph No. 10 (University of Sussex, United Kingdom). It draws from earlier published works of mine, see especially SIPRI, *The Problem of Chemical and Biological Warfare* (Vols. I, II, and V; New York: Humanities Press, 1971–1973); and *CBW, An Introduction and a Bibliography* (Los Angeles, Calif.: California State University, Center for the Study of Armament and Disarmament, 1974).

Big bangs from little bombs

U. S. Army launcher vehicle is part of an extraordinary proliferation of tactical nuclear weapons.

BARRY SCHNEIDER

The United States has over 30,000 nuclear weapons at home, at sea, in Europe, and in Asia. Of these weapons, 8,500 are considered strategic weapons; 22,000, tactical weapons. The main difference between strategic and tactical nuclear weapons is the difference in range. Tactical nuclear weapons have a shorter range but are sometimes more powerful than strategic weapons. As of mid-1975, the 8,500 U.S. strategic nuclear weapons are on these multiple-warhead carrying delivery vehicles:

- the 1,054 U.S. land-based Minuteman and Titan missiles,
- the 656 Polaris/Poseidon missiles on the 41 U.S. ballistic missile submarines, and
- the nearly 500 U.S. SAC bombers.

The United States has been producing strategic nuclear weapons at the rate of three per day for the past four years, and the total promises to grow to about 21,000 U.S. strategic nuclear weapons under the limits set by the November 1974 U.S.-USSR Vladivostok Agreement.

Less publicized and understood is the fact that nearly 22,000 U.S. *tactical* nuclear weapons are in the possession of the U.S. armed forces and that they are widely dispersed.

In Europe, the United States and its NATO allies have 2,250 aircraft, missile launchers, and nuclear cannons that can deliver 7,000 U.S. tactical nuclear weapons. These weapons carry a combined explosive capability equivalent to an estimated 460 megatons (or 460 million tons) of TNT—roughly 35,000 times greater than the nuclear weapon that destroyed Hiroshima in 1945. These U.S. tactical nuclear weapons are in all NATO European states with the exception of Norway, Denmark, Luxembourg, and France. France maintains its own tactical nuclear weapons in France and Germany. U.S. nuclear forces in Europe are most heavily concentrated in West Germany where 207,000 U.S. military personnel are based.

U.S. tactical nuclear weapons in Europe include at least four different kinds of surface-to-surface missiles (Lance, Sergeant, Honest John, and Pershing), two sizes of nuclear artillery shells (155 mm and 203 mm), and over 500 U.S. nuclear capable

---

Barry Schneider is a research staff associate at the Center for Defense Information in Washington, D.C. This article appeared in part in the February 1975 issue of *The Defense Monitor*, a publication of the Center.

fighter-bombers. The aircraft can be loaded with air-to-surface missiles and bombs. The largest tactical nuclear missile has 400 kilotons (or 400,000 tons) in explosive power, equivalent to over 30 Hiroshimas. The Pershing surface-to-surface missile and nuclear-loaded fighter-bomber are capable of attacking targets inside the Soviet Union from Western Europe.

The first U.S. tactical nuclear weapons were introduced in Europe in 1954, three years before the Soviet Union did so. Since that time the U.S. arsenal has grown dramatically and has undergone extensive changes as new U.S. tactical nuclear weapons replaced older ones. Soviet tactical nuclear deployment in Europe began in 1957, and the growth of their arsenal has been slower and shows little weapon turnover. Soviet weapons in Europe have accumulated without much retirement of earlier weapons. There are two U.S. tactical nuclear weapons for each Soviet tactical nuclear weapon in Europe: U.S. forces in Europe have 7,000 tactical nuclear weapons to 3,000 to 3,500 for Soviet military forces in Europe.

The U.S. armed forces deployed nuclear weapons to Europe in the early 1950s to offset numerically superior Soviet forces in Central Europe. At the time the Eisenhower administration was seeking to check Soviet manpower advantages through a strategic policy which threatened "massive retaliation," and U.S. tactical nuclear weapons in Europe were part of that policy. When the United States first placed tactical nuclear weapons in Europe the Soviets had no tactical nuclear weapons. By the late 1950s the U.S. monopoly on tactical nuclear weapons was ended.

Far less information has been released to the public by the Pentagon about the estimated 1,700 tactical nuclear weapons that the United States maintains on land in Asia. U.S. tactical nuclear weapons reportedly are in Korea and the Philippines as well as at U.S. installations in Guam and Midway.

The United States today has approximately 7,000 strategic and tactical nuclear weapons at sea. There are 284 ships and submarines in the U.S. Navy that can carry nuclear weapons. In 1965, only 38 percent of U.S. ships could carry nuclear weapons. Today the percentage is 55 percent and it is increasing each year.

The U.S. Navy is capable of delivering up to 12,000 tactical nuclear weapons in bombs, depth charges, torpedoes and missiles. Many of these weapons are capable of carrying both conventional and nuclear explosives. A conservative estimate places the number of U.S. tactical nuclear weapons at sea at 2,500. This number of weapons carries an explosive punch equivalent to 150 megatons of TNT, more than 75 times the amount of explosives dropped from 1941 to 1945 on Germany and Japan by U.S. bombers. Over 90 percent of this nuclear destructive power is found in the 1,400 tactical nuclear weapons aboard 14 U.S. aircraft carriers.

An estimated 14,800 U.S. nuclear weapons are kept in the United States: 4,000 strategic nuclear weapons are at U.S. Minuteman and Titan missile sites and at SAC bomber bases. An additional 10,000 U.S. tactical nuclear weapons are estimated to be in the custody of U.S. forces in the United States. The seven Army divisions on active duty in the United States have the full spectrum of tactical nuclear weapons, as do the U.S. Navy and U.S. Air Force units stateside.

Weapons in Search of a Doctrine

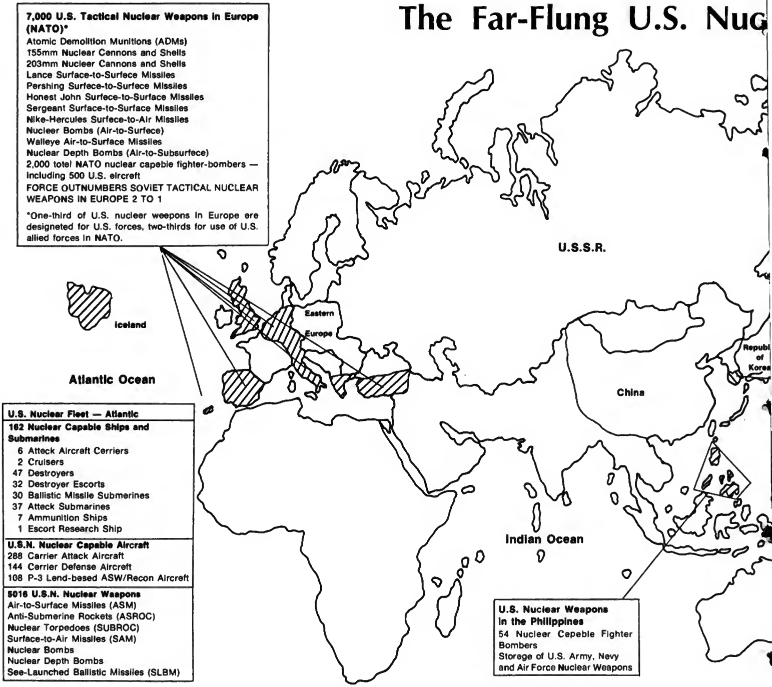
There is no rational doctrine for use of the U.S. land-based tactical nuclear weapons in Europe and Asia. Much is inherently wrong with a strategy which, if implemented, would destroy the country it is designed to defend. The use of 10 percent of the 7,000 U.S. tactical nuclear weapons in Europe would destroy the entire area where such massive nuclear exchanges occurred. War games practiced by NATO troops indicate the tremendous collateral damage that would be inflicted upon cities and people bordering the battle area. A NATO war game named Carte Blanche was run for 48 hours during which 335 tactical nuclear weapon explosions were simulated, 268 on German territory. A very conservative estimate placed Germans killed at between 1.5 and 1.7 million plus an additional 3.5 million people wounded. In the six years of World War II, 305,000 Germans were killed and 780,000 were wounded. Thus a very limited tactical nuclear war of this scope would produce over five times as many German casualties in two days as occurred in World War II.

Once the nuclear threshold has been broken and nuclear weapons have been used, it is highly likely that nuclear exchanges would escalate. The pressures to destroy the adversary's nuclear forces before they land a killing blow could easily lead to preemptive attacks. In the confusion, subtle peacetime distinctions between lower level tactical nuclear war, higher level tactical nuclear war, and all-out spasm nuclear war, would vanish. Once the threshold is crossed from conventional warfare to nuclear warfare, the clearest "firebreak" on the path to complete nuclear holocaust will have been crossed.

One risk of developing tactical nuclear weapons, especially those now euphemistically called mini-nukes, is that they may create the illusion that a limited nuclear war can be fought. Small weapons such as the 155 mm nuclear artillery projectiles have already been introduced. The trend is for more of the same. As smaller, 'cleaner,' and more accurate tactical nuclear weapons are added to the U.S. arsenal, they will add to the dangerous illusion that tactical nuclear weapons can be used with no risk of escalation.

This overlooks two factors. First, the U.S. tactical nuclear arsenal is still loaded with many large Hiroshima-size weapons. Second, the Soviet Union would respond massively to U.S. nuclear attacks.

The Far-Flung U.S. Nuc



7,000 U.S. Tactical Nuclear Weapons in Europe (NATO)*
Atomic Demolition Munitions (ADMs)
155mm Nuclear Cannons and Shells
203mm Nuclear Cannons and Shells
Lance Surface-to-Surface Missiles
Pershing Surface-to-Surface Missiles
Honest John Surface-to-Surface Missiles
Sergeant Surface-to-Surface Missiles
Nike-Hercules Surface-to-Air Missiles
Nuclear Bombs (Air-to-Surface)
Walleye Air-to-Surface Missiles
Nuclear Depth Bombs (Air-to-Subsurface)
2,000 total NATO nuclear capable fighter-bombers — including 500 U.S. aircraft
FORCE OUTNUMBERS SOVIET TACTICAL NUCLEAR WEAPONS IN EUROPE 2 TO 1

*One-third of U.S. nuclear weapons in Europe are designated for U.S. forces, two-thirds for use of U.S. allied forces in NATO.

U.S. Nuclear Fleet — Atlantic

162 Nuclear Capable Ships and Submarines
6 Attack Aircraft Carriers
2 Cruisers
47 Destroyers
32 Destroyer Escorts
30 Ballistic Missile Submarines
37 Attack Submarines
7 Ammunition Ships
1 Escort Research Ship

U.S.N. Nuclear Capable Aircraft
288 Carrier Attack Aircraft
144 Carrier Defense Aircraft
108 P-3 Land-based ASW/Recon Aircraft

5016 U.S.N. Nuclear Weapons
Air-to-Surface Missiles (ASM)
Anti-Submarine Rockets (ASROC)
Nuclear Torpedoes (SUBROC)
Surface-to-Air Missiles (SAM)
Nuclear Bombs
Nuclear Depth Bombs
Sea-Launched Ballistic Missiles (SLBM)

U.S. Nuclear Weapons in the Philippines
54 Nuclear Capable Fighter Bombers
Storage of U.S. Army, Navy and Air Force Nuclear Weapons

▨ **Key:** Areas Where U.S. Nuclear Weapons are Located

Source: Center for Defense Information, Defense Monitor, 4:2 (February 1975), 6–7.

Even if all the larger U.S. tactical nuclear weapons were replaced by new mini-nukes, using them would trigger the older, bigger, and 'dirtier' Soviet weapons with the same consequences for persons living in the area and the same resultant escalation.

The idea of a limited nuclear war is an illusion. However, it may encourage policy-makers to be more reckless and make nuclear war, especially during acute crises, more likely.

There are four dilemmas made possible by the spread of nuclear arms:

Dilemma 1: Nuclear Terrorists. The risk of war with the Soviet Union has long been regarded as the primary threat to the security of the United States. In hopes of averting such a catastrophe, thousands of man-years have been spent by analysts exploring how such a war is likely to erupt.

The research and contingency plans designed to control escalation of crises and limited wars, to prevent accidental war or unauthorized attacks, and to deter a surprise attack may be ignoring a likelier danger to Americans—the nuclear terrorist.

Weapons Arsenal

U.S. Tactical Nuclear Weapons Abroad	
Europe	7000
Atlantic Fleet	1000
Asia	1700
Pacific Fleet	1500
Total	**11,300**

U.S. Strategic Weapons At Sea	
Atlantic	4016
Pacific	526
Total	**4544**

U.S. Nuclear Weapons In South Korea

- 155mm Nuclear Cannons & Shells
- 203mm Nuclear Cannons & Shells
- Honest John Missiles
- Nike-Hercules SAMs
- Nuclear-Capable F-4 aircraft
- Nuclear Bombs
- Air-to-Surface Missiles
- Atomic Demolition Munitions

U.S. Nuclear Fleet —Pacific

122 Nuclear Capable Ships and Submarines

8	Attack Aircraft Carriers
3	Cruisers
38	Destroyers
32	Destroyer Escorts
11	Ballistic Missile Submarines
20	Attack Submarines
10	Ammunition Ships

U.S.N. Nuclear Capable Aircraft

384	Carrier Attack Aircraft
192	Carrier Defense Aircraft
108	P-3 ASW/Recon. Aircraft

2028 U.S.N. Nuclear Weapons

- Air-to-Surface Missiles (ASM)
- Anti-Submarine Rockets (ASROC)
- Nuclear Torpedoes (SUBROC)
- Surface-to-Air Missiles (SAM)
- Nuclear Bombs
- Nuclear Depth Bombs
- Sea-Launched Ballistic Missiles (SLBM)

A half-dozen terrorists with a home-made or hijacked nuclear weapon could cause thousands of deaths in a city like New York. One of the hundreds of U.S. nuclear bombs in the one megaton range, if exploded on Manhattan Island, would inflict casualties exceeding the *combined* totals of the war dead from the American Revolution, the War of 1812, the Mexican War, the U.S. Civil War, the Spanish-American War, World War I, World War II, the Korean War, and the Vietnam War. Nearly 1-1/2 million people would perish in such an event.

More than 50 major terrorist groups are reported to exist worldwide. Urban guerrilla activities, Olympic murders, airplane hijackings, terror bombings, and airport massacres are all well known.

How safe are nuclear weapons from theft by terrorist groups? Not very, according to the few indicators available in this highly classified area. U.S. Army Special Forces exercises have shown that nuclear weapons storage areas can be penetrated successfully without detection despite guards, fences, and sensors. Their example could obviously be accomplished by a daring and well-organized terrorist organization.

The United States, its allies, and the Soviet Union have now deployed thousands of nuclear weapons across the world, each in an effort to bolster its own national security. In doing so, these governments have made their societies more vulnerable to the nuclear terrorist.

Dilemma 2: Seizure by Allies. More than half of U.S. nuclear weapons are stationed abroad or on the high seas. Countries where U.S. nuclear weapons reportedly are stationed include Belgium, Federal Republic of Germany, Greece, Iceland, Italy, Republic of Korea, Netherlands, Philippines, Portugal, Spain, Turkey and United Kingdom.

Once the United States deploys nuclear weapons to an allied country, we put in jeopardy our control of those weapons if that nation ever becomes unfriendly to the United States. Allied seizures of U.S weapons could result in the United States having to fight its way into an allied country in order to rescue its own weapons.

This scenario takes on more plausibility in the light of the recent Greek and Turkish fighting on Cyprus. Both Greece and Turkey are host countries for U.S. tactical nuclear weapons and U.S. security forces were put on maximum alert guarding these weapon compounds during the short war between these two NATO allies.

Too many of the allied host countries that permit U.S. nuclear bases are dictatorships with oppressive regimes that spark dissent. Franco of Spain and Chung Hee Park of Korea are vintage examples of the genre. Some allies who permit U.S. nuclear weapons on their soil already have domestic insurrections on their hands; the Philippines and the United Kingdom are current examples. In Greece and Portugal recent coups d'etat have changed the complexion of the ruling groups.

In countries plagued by civil wars and coups, U.S. tactical nuclear bases may not be safe from our allies. During internal political disruptions in allied countries, U.S. bases might find themselves caught in the middle of a firefight. One side or the other might find it advantageous, or even necessary, to seize U.S. tactical nuclear weapons to gain the upper hand in the local struggle. Nor can we discount the possibility that allies, such as the Republic of Korea, might seize U.S. weapons in order to defend themselves or to possibly attack neighboring states, such as North Korea.

'Broken Arrows'

A "broken arrow" is the military term for an accident involving a nuclear weapon. The Pentagon has acknowledged 11 of them. Little is known publicly about six of the accidents. Here are details on the other five:

1. **Aircrash over Palomares, Spain.** On January 17, 1966 an American B-52 bomber collided with a KC-135 refueling tanker causing the deaths of five crewmen and the dropping of 4 hydrogen bombs which were recovered after an intensive ground and sea search. Radioactive leakage and conventional explosions occurred in the area.
2. **Bomb Accidently Dropped over South Carolina.** On March 11, 1958 a B-47 bomber accidently dropped a nuclear weapon in the megaton range over Mars Bluff, South Carolina. The conventional explosive "trigger" of the nuclear bomb detonated leaving a crater 75 feet wide and 35 feet deep. One farmhouse was obliterated. Luckily no nuclear radiation leakage was detected, no nuclear explosion occurred and no one was killed.
3. **Bomarc Missiles Burned in Fire.** On June 7, 1960, a fire at McGuire Air Force Base led to a series of shattering explosions and the destruction of one of 56 nuclear armed Bomarc missiles. While no nuclear explosion occurred there was a small amount of radioactive leakage creating a temporary health hazard.
4. **24-Megaton Bomb Safety Devices Sprung.** In 1961 a near catastrophe occurred at Goldsboro, North Carolina, when a B-52 bomber had to jettison a 24-megaton bomb. Five of the six interlocking safety devices were set off by the fall. A single switch prevented the bomb from exploding, an explosion which would have been over 1,800 times more powerful than the Hiroshima bomb.
5. **Greenland Air Crash Scatters Plutonium.** On January 21, 1968 a B-52 attempting an emergency landing at Thule Air Force Base, Greenland, crashed and burned on the ice of North Star Bay. The high explosive components of all four nuclear weapons aboard detonated producing a plutonium-contaminated area of at least 300–400 feet wide and 2,200 feet long. — B.S.

Dilemma 3: Unauthorized Use of Weapons. The danger of misuse of U.S. nuclear weapons increases dramatically with the number of persons who are involved in their production, transportation, storage, security, and wartime use. Yet the 30,000 U.S. strategic and tactical nuclear weapons are handled by many thousands of people, including U.S. military personnel, NATO allies, security guards, scientists at weapons labs, and shipyard and arsenal workers. Overall it is estimated that about 120,000 persons have access to U.S. nuclear weapons and weapons-grade fissionable material.*

While these positions are carefully screened by the Human Reliability Programs set up by the U.S. government, there have been problems with the people who handle and would fight with nuclear weapons. An average of three persons per thousand in the U.S. armed services have been identified as suffering from mental illness serious enough for professional care. Congressional testimony indicates that 3,647 persons with access to nuclear weapons were removed from their jobs during a single year because of mental illness, alcoholism, drug abuse, or discipline problems. Of the discharges which occurred in 1972 and 1973, 20 percent were for drug abuse.

Dilemma 4: Nuclear Accidents. The dispersion of 30,000 U.S. nuclear weapons across the world's oceans, in dozens of ports, in numerous countries in Europe and Asia, and in the United States creates risks of accidents of unprecedented magnitude.

The Department of Defense has admitted at least 11 "Broken Arrows," or major nuclear weapon accidents. The Atomic Energy Commission reports at least four other accidents involving various components of nuclear weapons while in the agency's control. There is evidence that many other unreported and unconfirmed nuclear accidents have occurred since World War II. Serious students of the problem estimate that an average of at least one U.S. nuclear weapon accident has occurred every year since 1945.**

Most of the U.S. tactical nuclear weapons overseas can be brought home with no loss in national security. Indeed, there should be a net gain in security as the chances decrease for accidents, for theft, and for unauthorized use of the weapons. Increased U.S. national security would be the result of adoption of the following recommendations:

1. *Remove all Quick Reaction Alert Aircraft (QRA).* Such systems are vulnerable to a surprise attack and lend themselves to the danger of hair trigger reactions and unauthroized use by U.S. and NATO pilots. Their missions can be taken over and performed more effectively by the ballistic missile submarine fleet.

2. *Remove all forward deployed atomic artillery.* Such weapons are subject to unauthorized use if forward units are surrounded and under attack. Moreover they might be easily captured if not used and turned against the NATO army they were designed to serve. Their forward deployment makes it likely that any war in Europe will be nuclear.

3. *Remove all forward deployed atomic demolition munitions (ADMs) and all of those not permitted to be prechambered where that is necessary.* Forward deployed ADMs, even if prechambered, would guarantee nuclear escalation of a conventional conflict—something to be avoided. ADMs that have not been prechambered to the optimal depth can cause excessive nuclear fallout and high damage to surrounding civilians and troops.

4. *Remove aircraft and surface-to-surface missiles capable of hitting targets in the Soviet Union or deploy them to the rear where their status as tactical weapons is clear to the USSR.* This also reduces the danger of unauthorized launching of bombs and missiles by U.S. forces directly against the Soviet Union.

---

*C. Walske, Asst. Sec. of Defense, Statement to Subcom. on Military Applications of Joint Com. on Atomic Energy, U.S. Congress, May 22, 1973, part 2, p. 6.

**J. Larus, *Nuclear Weapons Safety and Common Defense* (Columbus, Ohio: Ohio State University, 1967), pp. 4, 165–167; M. Leitenberg, "Accidents of Nuclear Weapons and Nuclear Weapon Delivery Systems," *SIPRI Yearbook, 1968/69* (New York: Humanities Press, 1969), pp. 259–270; Leitenberg to author, Dec. 4, 1974.

5. *Remove all nuclear weapons from U.S. aircraft carriers.* Carrier aircraft have no strategic nuclear role that cannot be better carried out by other systems. Carriers are unlikely to exist for long in a nuclear war and their primary remaining useful mission is as mobile launching platforms for aircraft engaged in conventional bombardment in limited wars. Nuclear weapons aboard would degrade the capability of the carriers to perform that role.

6. *Remove all nuclear weapons from South Korea, the Philippines, and other Asian states where they exist.* Such U.S. weapons pose dangers of theft, unauthorized use, allied seizures, and accidents. They threaten to involve the United States in areas where we would be forced to intervene. Such situations not only make our foreign policy hostage to our weapons policy but might force the United States to create another precedent of nuclear first-use.

7. *Substantially cut the number of U.S. nuclear weapons in Europe.* Perhaps 500 weapons would be enough to guarantee the participation of the U.S. strategic deterrent forces, yet this number would substantially cut the safety problems and costs of maintaining the force. Phasedowns could be gradual (e.g., 1,000 per year) and might serve to produce similar Soviet phasedowns as the danger to them somewhat receded.

8. *Restructure the remaining tactical nuclear weapons in Europe so that they are under the continuous operational control of the supreme commander of* NATO (SACEUR). Weapons should be taken away from frontline field commanders of local units and deployed in the rear. This will improve security and control of these weapons.

9. *Substantially increase the security precautions around U.S. nuclear weapons compounds and more intensively screen U.S. personnel who handle tactical nuclear weapons.*

10. *The program to "modernize" tactical nuclear weapons should be shelved.* Nothing is gained by their introduction and the dangers of creating illusions of "usable" nuclear weapons and blurring the distinction between conventional and nuclear war both increase rather than reduce the threat to U.S. national security.

11. *Nuclear capable missiles, and missile launchers, should not be sold or given to countries that have a near-nuclear capability.* To do so increases the risks of new countries "going nuclear" and increases the dangers to U.S. security thereafter.

'Peaceful' nuclear explosions

Nations must seal off this back-door approach to acquiring weapons stockpiles

ALVA MYRDAL

The whole apparatus of international treaties or agreements regarding the acquisition of nuclear explosive capability is now being questioned because of the underground explosion by India of a peaceful nuclear device in May 1974.

As India had never signed or ratified the Treaty on the Non-Proliferation of Nuclear Weapons of 1968 (the NPT), this treaty was not violated. India had, however, signed and ratified the Partial Test Ban Treaty of 1963 which banned nuclear weapon tests in the atmosphere, in outer space and under water. But there was a loophole left open in this Treaty and India used it, and used it in a way which ought to serve as an eye-opener: the implicit right to test nuclear explosives *underground.*

As for its being a peaceful (vs. military) nuclear explosion, there are no grounds whatsoever for making special exceptions for some nuclear explosions which are termed *peaceful.* The NPT, nevertheless, made this distinction; it was obviously an attempt to keep nuclear devices in the hands of the nuclear weapon nations, particularly the superpowers.

The NPT promised that the benefits from any peaceful applications of nuclear explosions would be made available to the non-nuclear parties to the Treaty at low cost. And it also stated that:

> Non-nuclear-weapon States Party to the Treaty shall be able to obtain such benefits, pursuant to a special international agreement or agreements, through an international body with adequate representation of non-nuclear-weapon States. Negotiations on this subject shall commence as soon as possible after the Treaty enters into force.

But no negotiations on the subject have taken place, no international agreements have been reached, and no benefits have been made available. The promises were made simply in order to get a discriminatory situation accepted.

Initially, the exploding of nuclear devices was seen exclusively in military terms—the use of nu-

---

Alva Myrdal, a disarmament expert, was the chief Swedish delegate to disarmament negotiations in Geneva and at the United Nations from 1962 to 1974. She has also served as the Swedish Ambassador to India and as a member of the Swedish Cabinet in charge of disarmament affairs. This article is based in part on her forthcoming book, "The Right to Conduct Nuclear Explosions," which will be part of the Stockholm International Peace Research Institute series on the problems of nuclear-weapon proliferation.

clear weapons in war or the testing of such weapons—and little attention was paid to the possibility of using them for non-military purposes. However, after a report was delivered to the second U.N. Conference on the Peaceful Uses of Nuclear Energy in Geneva in 1958, the forecasts of the economic benefits to be gained were optimistic, if not euphoric. Now, after many years of research the verdict is less enthusiastic. As the Soviet scientist V. S. Emelyanov sums it up:

> The possibilities of using nuclear explosions for civil purposes have been studied mainly in the United States and the Soviet Union. Both countries have been examining the feasibility of using nuclear explosions for exploiting oil and gas deposits, for opening up ore fields, for building water reservoirs in arid regions, for earth-moving operations in canal construction and so on. In the United States the Plowshare Program was established to implement a number of such projects; the Soviet Union's counterpart is "the program of use of commercial underground nuclear explosions." Such studies have so far been largely theoretical, and although much useful data has been obtained from test explosions, none of the projects under investigation has yet reached the stage of wide and practical application. The advantages of using nuclear explosions for such projects lie chiefly in saving labor and therefore money. However, the danger of subsequent radioactive contamination of the environment is very real: the problem of designing a 'clean' explosive has still not been solved. It is concluded that, at present, peaceful nuclear explosions are advisable only for exceptionally urgent problems which cannot otherwise be solved.[1]

The important fact is that there is no essential difference, except intent, between peaceful and military explosive devices; they are all bombs. In practice, however, technical details would be different, depending upon the detonating procedure selected: the degree of streamlining, and the different type of casings necessary for engineering projects or for military delivery vehicles, etc. The early R&D groundwork is the same, however. And the cost of development is usually borne by the military.

Nuclear Testing

There is general agreement that nuclear weapon R&D can neither be prohibited nor interfered with through direct verification. As the first critical step in the manufacture of nuclear weapons is testing, that is the step which can and should be under the most careful surveillance.

When the debate on nuclear-weapon tests first began, it was in connection with disarmament. The Antarctic Treaty of 1959 recognized the importance of nuclear testing, even though it did not mention weapons specifically: Article 5 of the Treaty states that "any nuclear explosions in Antarctica and the disposal of radioactive waste material shall be prohibited." It has been surmised that this sacrifice of an opportunity for technological experimentation was made in order to allay the apprehensions of the Latin American countries.[2]

In the Partial Test Ban Treaty of 1963 another approach was adopted. There the preamble emphatically sets the goal as "the discontinuance of all test explosions of nuclear weapons for all time," while Article 1 adds "or any other nuclear explosion." The signatories to the Treaty did not object to these words, which were included almost as an afterthought, although the United States initially wanted all peaceful explosions allowed. When the United States had to be satisfied temporarily with the sole possibility of conducting them underground, President Kennedy told the U.S. Congress that he hoped to arrive at a second agreement authorizing peaceful explosions under certain conditions.[3]

The Treaty of Tlateloco of 1967, which prohibits the testing, use, manufacture, storage, installation or deployment of nuclear weapons in Latin America, was the first multilateral disarmament agreement to raise seriously the question of explosions for peaceful purposes. Article 18, which is devoted to this subject, however, is rather ambiguous and it has since been interpreted in different ways.

When NPT negotiations were conducted in Geneva, it was members of the non-aligned nations of the then Eighteen-Nation Disarmament Committee that introduced queries and objections in a fairly concerted way with regard to peaceful nuclear explosions (PNEs).* The main question was one of discrimination. It has to be approached from different angles: if PNEs might yield considerable economic benefits, the lesser nations should be given an equal share in these techniques for enhanced development; or if the present pessimism about these benefits is more justified, the nuclear-weapon nations should be equally prepared to renounce PNEs in order, at least, to close the loophole for clandestine weapon testing.

When the case for a non-discriminatory solution was lost as far as the compromise version of the NPT was concerned, the non-aligned nations raised the issue again—hoping at least to get matters ironed out in connection with a test ban—at both the 1968 Conference of Non-Nuclear Powers held in Geneva and at the 1968 Eighteen-Nation Disarmament Conference. There was thus concerted pressure for a non-discriminatory way of dealing with nuclear explosions for specified peaceful purposes to be arrived at by international agreement. The arguments have been summed up as follows:

> Canada and Sweden maintained that an underground test ban treaty would have to include provision for specific permission for each peaceful nuclear explosion under an international regime for the peaceful utilization of nuclear energy. India agreed that the underground test ban was directly linked to the issue of peaceful explosions and that the two should be considered together. In its view, total prohibition of nuclear explosions must apply to all States, nuclear and non-nuclear. Peaceful explosions would then be permitted under a separate international regime. It also stressed that the development of a nuclear excavation technology must not involve any

---

*In 1970 the ENDC was expanded and renamed the Committee of the Conference on Disarmament (the CCD). Ed.

Peaceful nuclear devices are nothing but another loophole in the nuclear numbers game—and an escape clause for the superpowers.

modification of the Partial Test Ban Treaty, but be settled through a separately negotiated instrument within the context of a comprehensive test ban.[4]

It is regrettable that the test ban negotiations were not completed while non-proliferation was on the agenda. As long as the ban on testing nuclear explosive devices is incomplete, there can be no watertight reliance on non-proliferation. At the very least the connection between nuclear weapon tests and peaceful nuclear explosions should have been underlined. It is high time that this omission is rectified. Peaceful nuclear devices are nothing but another loophole in the nuclear numbers game, and the similarity between peaceful and military nuclear explosive devices is becoming of even greater significance when discussing nuclear proliferation today.

The PNE loophole acts as an escape clause for the superpowers, which became obvious after the 1974 Moscow agreement. The prescribed threshold of 150 kilotons as the upper limit for yields from underground nuclear tests is so high as to render the controls even more ineffectual. Seen in this light, statements like the following from one of the superpowers, the United States, take on all the appearances of verbal smokescreens:

> Since it is not possible to distinguish between the technology of nuclear devices for peaceful engineering purposes and that for nuclear weapons, the question of how a program for peaceful nuclear explosions might be carried out without violating the threshold treaty is a complicated one. Article III of the treaty commits the United States and the Soviet Union to pursue this problem in subsequent discussions. . . .
>
> It is important to develop a set of agreed procedures for peaceful explosions, as and if they become technically and economically feasible, to distinguish them clearly from weapons tests and make sure that they would not be used for weapons purposes.[5]

The hope held out here is that the two governments might work out "agreed procedures" for PNEs before their own bilateral and incredibly modest test ban enters into force in 1976. As both superpowers emphasize that the material economic value of PNEs is still very uncertain, there must be some other reason for not abandoning them. This could at least have been done temporarily until the question could be dealt with at the international level. But vague uncertainties are, of course, the very essence of loopholes: if ever the nuclear test ban became total, there would always still remain the seemingly innocent alternative of PNEs as a means of clandestine testing.

Even more important from the point of view of the international community is the foreclosing of negotiations on a comprehensive test ban. When by bilateral dictum a threshold for permitted underground explosions is set so ludicrously high as 150 kilotons for the military and no limit for peaceful explosions, any continued action at Geneva to introduce a much lower threshold is preempted. There had been envisaged a limit falling somewhere between less than 1 and 20 kilotons, depending on detection capabilities—the latter being the yield of a Hiroshima bomb.

The whole disarmament agenda item of a comprehensive test ban is now, of course, effectively killed by joint superpower action. That other nations would accept a lower threshold or a total ban is out of the question.

The tasks of the NPT review conference being held this month cannot be seen in isolation: to initiate, and ideally conclude, negotiations at international level on PNEs or, as a minimum, to obtain a moratorium on them until an agreed solution is found. To find a solution without loopholes also requires the clearing up of anomalies in the test ban treaties which have crept in as a result of the introduction of threshold limitations, bilaterally at Moscow and as pending proposals also in the Geneva Disarmament Committee (the CCD).

Uses and Effects of PNEs

Findings on the unfortunate environmental effects of nuclear explosions have a bearing on the Partial Test Ban Treaty; it may have to be amended.

As nuclear explosions are forbidden except underground, PNEs can legitimately only be available for mining operations. If gas, oil or minerals in any quantities are to be extracted by nuclear mining, the explosions would have to occur in great numbers. Underground tests have already created considerable radioactive fallout. When it spreads through the atmosphere beyond national boundaries it is a contravention of the Partial Test Ban Treaty. The nuclear weapon parties to the Treaty seem to treat this issue with mutual indulgence, calling such occurrences 'technical' violations. Other nations, notably Japan and Sweden, however, have expressed concern on the subject and have made protests through diplomatic channels.

The issue of whether or not any level of such contamination of the Earth's atmosphere is permissible should be categorically decided: that is, whether or not even a release of infinitesimal strength is legally condoned. This issue takes on new significance if PNEs become tolerated.

It has also been proposed that PNEs be used to excavate canals and harbors or change the course of rivers. These applications would have even more serious implications for the environment, as fallout would be even more extensive. An idea of what may be involved can be gained from assessing the nuclear costs of digging a sea level Panama Canal—some 300 nuclear explosions with yields ranging up to 15 megatons would be required.

Recently, the possibility of nuclear explosions destroying the Earth's ozone layer has been raised. When the director of the U.S. Arms Control and Disarmament Agency, Fred Ikle, spoke of this danger, he did so in relation to the potential effects of nuclear war, but the implications are clear for other uses of such explosions:

> We do know that nuclear explosions in the Earth's atmosphere would generate vast quantities of nitrogen oxides and other pollutants which might deplete the ozone that surrounds the Earth. But we do not know how much ozone depletion would occur from a large number of nuclear explosions—it might be imperceptible, but it also might be almost total. We do not know how long such depletion would last—less than one year, or over ten years. And above all, we do not know what this depletion would do to plants, animals and people. Perhaps it would merely increase the hazard of sunburn. Or perhaps it would destroy critical links of the intricate food chain of plants and animals, and thus shatter the ecological structure that permits man to remain alive on this planet. All we know is that we do not know.[6]

But, if cratering PNEs were to be legitimized an amendment to the Partial Test Ban Treaty would be necessary, and this could be achieved only with the consent of a majority of the over 120 states who have either signed or ratified the Treaty. So for once the non-nuclear-weapon nations are in a strong position to veto any such attempts at an amendment.

Proposed Long-Term Solution

Given this situation, and in view of the very important proliferation prospect if PNEs are permitted, it is highly questionable whether there would be any value in pressing for international negotiations now on Article 5 of the NPT. The main task at the NPT review conference will be to keep the peaceful nuclear explosion issue alive and to outline an agenda for a long-term solution. A convincing solution, however, can only be found in conjunction with a comprehensive test ban. A model for a long-term solution without loopholes is presented below; it places the proscriptions for nuclear explosions for peaceful purposes in a protocol to a comprehensive test ban treaty, which would ban all military nuclear test explosions.

If a comprehensive test ban is to become a reality, a new synthesis must be found between political and technical considerations. As India is the cause of the present alarm, let us look at how India now formulates the conditions for a non-discriminatory solution, to which India would presumably adhere:

> We can make a beginning in controlling the nuclear arms race by agreeing on a comprehensive test ban. We feel that there is no justification or excuse for continuing nuclear-weapon testing. . . . Only in the context of a complete cessation of all nuclear-weapon tests could consideration be given to the possibility of concluding an agreement on the regulation of underground nuclear explosions for peaceful purposes to be signed by all States. The accompanying system of international safeguards which will have to be devised should be based on objective, functional and non-discriminatory criteria. It should be universal in application.[7]

In 1968 the non-aligned nations of the Geneva Committee had recommended an international regime for conducting, or at least licensing, all PNEs, and had linked this solution to a comprehensive test ban.[8] However, the form and the functions of such an international regime for handling PNEs have not as yet received close scrutiny. Before any agreement for the international regulation of PNEs referred to in Article 5 of the NPT can even be drafted, the basic issue of principle must be resolved: to arrive at a proper division of functions between the licensing authority—with power over the very permission to undertake any explosion with its grave military implications—and the managing authority—with the obligation to assure that rules about technical feasibility, health safeguards, etc., are strictly followed.

Because of the need to assure that the PNEs will not be coupled with military nuclear test explosions a debate is urgently needed on how to separate the licensing authority and the managing authority functions of an international regime. The International Atomic Energy Agency is clearly the organization which should undertake the latter function, and should be given the means to build up the necessary structure, both legal and administrative, for performing managing authority functions and services.

The licensing authority of the international regime, the one which is of paramount interest from the disarmament point of view, has receded far into the background: the need for an impartial authority to decide on the right of a party to undertake nuclear explosions. That this has occurred is quite understandable, as it immediately raises the vexing question of the right to undertake explosions for any purpose—peaceful or not—as the devices themselves inherently have a dual purpose.

The superpowers' resistance to any international regulation of the right to conduct PNEs is political in nature, as they continue to believe that nuclear-weapon powers should have the right to conduct them without such international accountability as licensing implies.

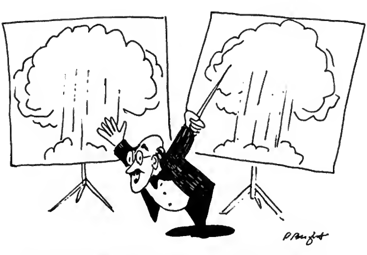
For the decision-making or licensing authority a locus must be sought where non-discriminatory political responsibility can be exerted. It is difficult to envisage, however, how such a function could be handed over to an existing body. The IAEA governing board has a disproportionately high number of representatives from the technologically advanced nations. The U. N. Security Council has a pattern of veto rights which would render it ineffective as a licensing agency. The U.N. Economic and Social Council might possibly be entrusted with these tasks, although anything where disarmament and development are interrelated to such a degree has never before been laid on its shoulders. Thus, I have advocated the establishment of a new agency, an international disarmament control organization (IDCO), which would permanently monitor all problems pertaining to agreements in the disarmament field and would also be able to prepare background information for ad hoc cases.[9]

In any event the body in which final authority is vested must be directly responsible to a constituency of the parties to each international agreement concerned, in this case the Non-Proliferation Treaty and the proposed comprehensive test ban treaty. The first step, however, should be the compilation of a comprehensive report on nuclear peaceful explosions, a report of the kind which the U.N. Secretariat has organized on many other occasions with great benefit as, for example, on chemical weapons and the costs of the armaments race.

In his latest annual report, the U. N. Secretary-General suggested that all aspects of peaceful nuclear explosions should now become a subject for "international consideration." A resolution was dutifully passed by the General Assembly in 1974, but it only requested that the IAEA continue its studies on the utility and feasibility of PNEs, including legal, health and safety aspects. The resolution further called on the Conference of the Committee on Disarmament (the CCD) to consider the arms control implications of PNEs, and expressed the hope that the NPT review conference will also give consideration to the role of PNEs, "as provided for in the treaty." Vagueness thus scored again.

A moratorium on PNEs would be a welcome step in the direction of a more effective universal ban. Inasmuch as the superpowers are having second thoughts on the value of PNEs a moratorium may be possible. (A moratorium on weapons testing was urged by U.N. General Assembly Resolution 3257 (XXIX) 1974, but not on peaceful testing.)

The major task, however, is to achieve a universal, non-discrimnatory ban on *all* nuclear explosions. The most reasonable course would be to halt all nuclear-weapon tests, immediately and unconditionally. Their continuance runs counter not only to disarmament efforts but also to the interest of keeping a balance in the nuclear arms race. The superpowers though have hitherto not been inclined to take such a rational view. Through their bilateral 1974 agreement on a threshold test ban they have indicated that they want to keep their options open for producing new nuclear-weapon systems.



And here we have a peaceful nuclear explosion. Please, notice the peaceful posture of this device, not like this warlike device on my right.

But the statesmen leading even the great nations of the world are not so free of their own military authorities and planning engineers that they can win approval overnight for an immediate shutdown of all on-going weapon tests and operating weapon-test sites, so it is necessary to discuss methods of ending nuclear test explosions over a more prolonged period of time, say a couple of years. Considerations of this sort led the Swedish delegation to the Geneva disarmament conference to present a draft treaty banning all underground nuclear weapon tests.[10] Protocols to this draft treaty were envisaged to allow different time lapses before various proscriptions enter into force.

The idea behind a timetable approach is that the decision to stop all nationally decided and conducted nuclear explosions should be made first—within the not too distant future—and that full international control should be introduced as soon as possible. What is 'peaceful' about nuclear explosions should then no longer be an enigma.

A major question remains unanswered, however. Should this decision on the permissibility of nuclear explosions—peaceful or military—be decided by the NPT signatories alone? Or, isn't this issue a major one which directly affects the whole community of nations?

NOTES

1. Stockholm International Peace Research Institute, *Nuclear Proliferation Problems* (Cambridge, Mass.: The MIT Press, 1974), p. 215.

2. George Fisher, *La Non-Prolifération des Armes Nucléaires,* (Paris: Librairie générale de droit et de jurisprudence, 1969), p. 5.

3. Harold K. Jacobson, *Diplomats, Scientists and Politicians* (Ann Arbor, Mich.: University of Michigan, 1966), p. 463.

4. United Nations, *The United Nations and Disarmament,* 1945–1970 (New York: United Nations, 1970), pp. 244–245.

5. U.S. Arms Control and Disarmament Agency, Statement by Fred C. Ikle, ACDA Publication 73 (Washington, D.C.: The Agency, 1974), p. 3.

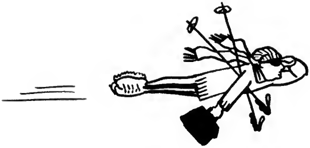
6. International Herald Tribune, Sept. 7, 1974.

7. U.N. General Assembly, A/C. 1/PV. 2016, Nov. 11, 1974.

8. Eighteen-Nation Disarmament Conference Memorandum 235, 1968.

9. A. Myrdal, "The International Control of Disarmament," *Scientific American,* Oct. 1974, p. 21.

10. See, for example, *SIPRI Yearbook 1972. World Armaments and Disarmament* (New York: Humanities Press, 1972), pp. 530–31; or Disarmament Conference document CCD/348, 1971.



NOTES ON THE WORLD, PART 3

The importance of point of view

Hong Kong, Japan and home

ROBERT GOMER

We are flying to Hong Kong via Bangkok. Things seem rather relaxed on the Royal Nepal Airline. Passengers wander into the cockpit to look and chat and by the time we approach Bangkok there are some 10 persons there. The countryside looks green and fertile and neat, crisscrossed by canals. We touch down, and the kibitzers leave the cockpit. The airport is vast and modern and clean. We are the only transit passengers and a vivacious hostess, with long shining black hair and enterprising eyes, takes charge of us. When Anne goes off to look at the duty-free shops, she flirts with me. Too soon, Anne has seen the silk ties and teak elephants and our tickets are taken care of.

The BOAC flight to Hong Kong is a pleasant surprise. The hauteur of yesteryear has given way to cheerfully efficient and attractive stewardesses. Even the food is excellent, and the whole ambiance, from the confident U voices of the officers to the crisp summer whites of the purser evokes the British virtues. How hard it is to generalize!

Hong Kong is beautiful beyond our expectations. The city reminds us a little of San Francisco, in its blend of ocean, bay, and hills. There is some irony in the fact that some of the older districts in this ultra modern, ultra rich town evoke the word Chinatown. Although our wanderings are hardly extensive enough to be conclusive, we get the feeling that even the large refugee population has been reasonably well absorbed, that there is, certainly by Asian standards, very little poverty. The public housing seems very much superior, if only in the way it is maintained by its occupants, to comparable public housing in American cities.

Although the recent refugees are almost exclusively Cantonese, the majority of the present population of 4 million consists of post-World War II immigrants, largely from Shanghai. It was this wave which changed Hong Kong's economy from an almost exclusive trade basis to the industry which gives it much of its present affluence. Hong Kong is quite obviously a very wealthy city, and it is far from a bargain paradise. Everything from food to suits and optical goods is relatively expensive.

The history of the Crown Colony's acquisition is not a very glorious page in British history. The original small military and mercantile station was expanded to its present size largely through the consequences of drug running. Hong Kong Island, for instance, was acquired in 1841 after England defeated China in the first opium war, which resulted when China balked at England's efforts to flood it with cheap Indian opium. Kowloon, on the mainland, was acquired after the second opium war in 1860. The New Territories, the colony's agricultural hinterland which supplies much of its food, was acquired in 1898 via a 99-year lease. It is improbable that these humiliating facts have altogether escaped the notice of China's present rulers. For the moment, the British presence offers evident advantages to China, but many people are uneasy about the colony's long range future.

* * *

One man who at least professes considerable uneasiness and probably with good cause is Dr. W. The W's are relations of a young physicist, long a U.S. resident, who has recently been working with me. It is clear from the conversation that they are not in close touch with him and are entertaining us more as a matter of family honor than anything else.

Any family, incidentally, could be proud of their effort. After lunch Mrs. W. arrives in their chauffeur-driven air-conditioned Chrysler limousine and takes us around the island; a visit to the Peak via funicular, while the chauffeur worries about parking; a drive to Repulse Bay on the other side of Hong Hong Island with its white sand beach and limpid blue water—it evokes Bermuda—and tea (which turns out to consist of crêpes au Grand Marnier), at the hotel there.

Now, in the evening, Dr. and Mrs. W. have taken us to a Mandarin restaurant, in Kowloon, where

---

The writer, a professor of chemistry at the University of Chicago, took a 50-day trip around the world in the winter of 1974. This article, last in a series of three, records his impressions.

A haze of shrimp steamed with ginger; a sweet mist of bean curd and taffy apples, with all sorts of fish and meat and vegetable dishes in between.

two of their children will shortly join us. Dr. W. speaks no English but quite good French, which his wife does not understand, so that we find it necessary to translate for her occasionally. Dr. W. dominates the conversation and does not bother much to include his wife. She seems to find this quite natural and, in effect, says as much, asserting at some point in our conversation that she believes in male superiority. What would the Sisters back home say? The quietly patrician Mrs. W. incidentally seems the stronger personality of the two.

Dr. W., short and chubby, seems to find a certain satisfaction in asserting that the communists, if they came, would shoot him as a capitalist, which he most assuredly is. He talks of emigrating to the United States and opening a restaurant, much as Lyndon Johnson might have talked of retiring to Texas to open a country store. The postwar history of the W's is probably not atypical; Dr. W. continued to work at his hospital in Shanghai after the communists took over but soon started to plan his emigration. The first to leave for Hong Kong was Mrs. W.; somehow Dr. W. got permission to visit her, and did not return. A 20-year-old daughter, then a baby, still lives in Shanghai, as do several old aunts. The Shanghai daughter cannot get out, and of course she is compromised by her defector parents. Although it is ungracious, considering how nice the W.'s are being to us, and what an excellent dinner we are having, I cannot help thinking that China is as well off without Dr. W. as Dr. W. is without China.

The dinner really is superb, ordered after lengthy and animated discussion between Dr. W., apparently well known here, and the headwaiter. It is built around Peking duck served in the three traditional courses, skin with pancakes, scallions and plum sauce; meat and vegetables; and finally (for the duck courses that is) soup made from the bones. However, all that is somewhere in the middle of the meal. The beginnings recede into a haze of shrimp steamed with ginger and the final courses fade into a sweet mist of beancurd and taffy apples, with all sorts of fish and meat and vegetable dishes in between. For once Anne's normal astuteness is dulled—no doubt by this embarras de richesse—and she keeps asking Mrs. W. whether she makes such and such a dish at home, to which Mrs. W. replies that no, despite her two full-time cooks, such and such is too difficult to make at home. I finally intervene and say that Anne should realize that we are having extraordinary delicacies which no household could possibly prepare. Mrs. W. flashes me a quick smile.

After dinner the W's son takes a number of pictures with very fancy looking Nikon equipment, the children are taken home by the chauffeur and we elders go for a short walk before brandy and coffee.

* * *

We are under way to Kyoto, our penultimate stop. Our reservations are finally in order, after a bad scare. At the very start of Anne's journey Air France's computer had somehow got the notion that we are both flying to Paris from Chicago, and is since avenging its disappointment by systematically cancelling our reservations throughout the rest of the trip. Most of the time we have been able to outwit it, but now it seems to have us cornered. It has cancelled our reservation to Osaka, and there will be no space available on any airline, despite the several daily flights, until midweek, long after the start of the conference. An interesting sidelight on the flow of businessmen to and from Japan, but one which we had just as soon not discovered. Anyway it all gets straightened out after some not so mock-angry conversations with Air France, and here we are in Osaka, somewhat apprehensive because of our total lack of Japanese. Needlessly so. At the airport enough English is spoken to get us on the bus to Kyoto. Although the driver speaks no English (very few Japanese do), a bilingual tape recording synchronized with the departure (and arrival in Kyoto) gives us all the information necessary.

The ride to Kyoto, some 30 miles, over very modern freeways with complicated cloverleaves and overpasses and underpasses never once passes through open country, although we see in the distance some hills which have not been built over. The smog is no worse than in Chicago.

We are staying at the Palace Side Hotel, officially described as second class although it is quite luxurious by our standards for non-U.S. lodgings and scrupulously clean. There is even a television set. The name of the hotel describes its location quite accurately, it faces the gardens of the Imperial Palace.

We don't venture far afield for our first meal but take the recommendation of the hotel desk, and go to a place just down the street. As usual a mistake. It turns out to be mod-Chinese with expensive, mock-Chinese food and entertainment, consisting of a small band and a very pretty girl singer who belts them out in English and Japanese. After dinner we wander around the neighborhood a bit. Somehow it seems familiar, despite the occasional pagoda roof, and makes a distinctly Western, almost American impression, except for the fact that it is much cleaner and neater.

In a small back street we come upon a tiny pastry shop. As in most Japanese eating establishments the window displays plastic replicas of the offerings, which look very tempting. We buy a piece of *tortu*, which turns out to be as good as the products of most Swiss or Austrian Konditoreis. Later during our stay we find that good pastry—Austrian, German, Swiss, but not the abominations which pass for French pastry in America (sad to say not entirely unknown in France)—is ubiquitous in Japanese cities. Is it one of the few marks left by the Axis period?

At the hotel our beds have been turned down, and kimonos and slippers laid out. On the television there is a volleyball tournament. Whenever the ball goes out of bounds a linesman waves a flag and the referee shouts, "*outo.*" After each game the teams line up in two parallel rows and bow to each other. Later we find this true also of baseball teams. The effect is immensely comic but also touching. The television programs seem very American to us, even the Samurai and robbers stuff, although we can't figure out who the bad guys are until the very end when they get killed because the good guys scowl, if anything, more fiercely. In addition to the standard commercials little squibs waft across the bottom of the screen during the program material.

The meeting, an international Congress on surface and vacuum phenomena, takes place in the fairly new International Conference Hall, an enormous abstract pagoda of glass, wood and steel, rather attractive. The location among pine covered hills on the shore of a small lake is very peaceful. Nearby the enormously tall net of a golf driving range mars the view. Golf is very popular but my guess is that most of it is confined to these driving ranges which one sees everywhere. The attendance at this meeting must be close to a thousand people, roughly ten times the optimum, and since the price of a ticket to Japan consists, for most of the participants, of a paper to be presented, there are enough papers to force the meeting into six parallel sessions. Unfortunately they are so arranged that almost everyone must miss a few things he would like to hear, and is forced to break into and out of sessions. It is very disconcerting for some of the less well-known (and even more disconcerting for some of the well-known) speakers to have the hall empty just before their talk.

Despite the vast masses of people surging through the building the usual microcosms soon establish themselves. I see friends and acquaintances from England, Germany, Australia, the States, Italy and, of course, Japan. It is amazing how many people over the years one has argued, shared an evening or corresponded with, or whom one has visited, or been visited by. Often one has not thought about someone for years, only to find an easy camaraderie re-establishing itself instantly during encounters like the present. Much of it of course is mutual reassurance—you are a good fellow and do good work and so am I—but often it goes beyond that. Even at a large meeting like this it is possible to get quite a bit of useful information on what people are doing, mostly over a cup of coffee or lunch, almost never from the formal talks which are so structured that there really isn't time for meaningful discussion, even if the size of the audience were not inhibiting.

* * *

During this week Anne and I see each other mostly in the evenings, and much of my sight seeing is vicarious. Anne has been exploring Kyoto and its temples on foot and by streetcar. I find it possible to take off one morning and one afternoon to join her. Somehow Kyoto continues to evoke familiarity, as if a view of the mountains here, a street corner there, had already been seen somewhere, sometime. Possibly it is only that the total impression is so unoriental, unexotic, despite the temples, and the Japanese roofs.

Nevertheless Kyoto has distinct character, and conveys a feeling of peace and calm. Partly this stems from the fact that its historic significance as the capital of feudal Japan from about 800 A.D. to the very end of the Shogunate in 1860 has spared it some of the progress which has occurred elsewhere; its setting amid pine covered hills and mountains helps too. From our hotel we can see patches of snow on Mount Hiei; it doesn't seem farfetched to imagine Genji seeing it pretty much the same way, 800 years ago, just finding time in a hasty poem to compare the snow of the plum blossoms to that of the mountain, while hurrying to an assignation.

The streetcars are a blessing and make it easy to get around. They will be put out of service in a month's time to make room for more car traffic. Anne has put off seeing Ryoanji temple with its famous rock garden by the artist Soami until we can see it together. A rectangular patch of sand, perhaps 15 by 25 feet, seven small rocks sticking out of it, no more, no less. Despite the crowd of people it seems to speak to each viewer individually. To me its speaks of spareness, serenity, and solitude.

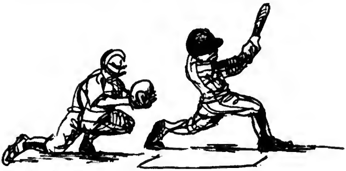
There is no need to imagine islands in a sea or mountain tops above clouds. The *Ding an sich* suffices. Above all I am startled by the sophistication. Soami's garden dates from the end of the 15th century. Next to it one can look into a room in the temple: bamboo mats; a few simple but exquisite pieces of furniture; the simplicity of a very aristocratic elite.

By now we have discovered where and how to eat sensibly, well, and not least cheaply, namely the myriads of unassuming neighborhood restaurants with their plastic displays. Although a Western dinner featuring steak or roast beef will not cost less than $20, for less than a tenth of that one can have a perfectly adequate meal built around a ramen dish—wheat or buckwheat noodles, with broth, a little meat and some vegetables, invariably served to be attractive to the eye as well as to the palate. Communication is no problem, one simply goes to the window and points.

* * *

There is a reception by the mayor of Kyoto at one of the downtown hotels this evening for some of the foreign visitors. The party starts a bit stiffly with a reception line like all such events, but food and drink are good and plentiful and loosen things up. There is a curious mixture of Western dishes, deviled eggs, casseroles, and Japanese delicacies: yakitori, a Japanese version of shishkebab; noodle dishes, prepared in situ; hot sake and excellent Japanese whisky, tasting very much like a good mellow Scotch. After a while there is a speech by the mayor followed by remarks by Leo Esaki, a young physicist working for IBM (in Yorktown) who received a Nobel prize last year for his invention of the so-called Esaki diode, a semiconductor device with a current-voltage curve like a roller coaster which makes it useful in a number of ways. Esaki's work is not particularly related to surface phenomena but he is Japanese and a Nobel prize winner, and from Kyoto. Also on hand is Hideki Yukawa, a theoretical physicist famous for his prediction of what is now known as the pi-meson, whose work has even less to do with surfaces; he too is a son of Kyoto and a Nobel laureate. Esaki and Yukawa are allowing themselves to be pointed to with pride, and even go so far as to sing with the mayor their old Kyoto high school song, which has something to do with saying "to hell with Schopenhauer." Esaki is very much the American hail fellow well met, but the bonhomie sits a little strangely on Yukawa.

Next day I read in the Japan Times an interview with Esaki in which he complains that the Japanese system of higher education tends to stifle creativity in the sciences. He is right, but he describes only a small facet of what for once must be called a national characteristic. The genius of Japan has *always* been to adapt rather than to innovate, to borrow from another culture and to make the borrowing peculiarly its own. It is curious how strongly this trait has persisted through the centuries. The first important borrowing, still of immense importance, was from the Chinese; it started almost 1,500 years ago and continued well into the Middle Ages. The next was from Europe and America in the 19th century. The last borrowing, almost wholly from America, commenced with the McArthur era, is still in progress and its ultimate effects obviously can't be assessed yet. It is amazing that the Japanese, who in most ways seem rigidly traditional, have always had this flexibility, and have been able to use it so well. The transformation of the Shogunate, a loose agglomeration of virtually independent fiefdoms controlled by local daimyos and samurai, into a modern nation-state was accomplished in less than a decade because enough of the leaders saw that the only way to prevent a takeover by the Western powers was to fight fire with fire, to become Westernized.



Yet what Esaki says is quite true. Transistors for instance were an American invention. Within a few years their manufacture and the manufacture of transistor-based devices had gravitated largely to Japan. Yet the logical next step, their miniaturization into so-called integrated circuits, which makes it possible to have the equivalent of some 30,000 transistor circuits on a chip of silicon the size of a fingernail, was again an American achievement. And once more: The miniature calculators based on integrated circuits have so far all come from America. Much the same applies to games. The most popular sports are baseball, volleyball, golf. Even Go, that marvellous game, is Chinese in origin. What makes the Japanese at once so flexible and adaptable and yet in some ways too rigid to push ahead, to invent? Perhaps their flexibility consists mainly in accepting any tradition, Japanese or foreign, as long as it is *a* tradition.

The conference depresses me a little. There is some innovative work presented, but by and large it has become clear that surface phenomena are now entering the stage of big science where money can be translated into apparatus sure to bring results. Not that the results are unimportant, or uninteresting, far from it; but somehow the aesthetic appeal, the feeling of treading entirely new paths is diminishing and that has always meant a great deal to me personally, an unabashed romantic of science. There are many scientists who would sneer at this attitude, and not only the entrepreneurs, the businessmen and politicans of science who suc-

The uniqueness which is Beethoven's or even Gibbon's seems denied to scientists. And yet scientists can be immortal, too. For there are styles in science as much as in art. . .

ceed as much by force of personality as anything else but also many whom I respect for being more than that. They are quite right of course, the end is more important than the means, but still. . . .

I have often wondered, in this connection what motivates research scientists. Of course one can speak with moderate confidence only of oneself, but since I am unlikely to be all that unique, my feelings are probably fairly widespread. There is a sort of historical development. In early youth one is fascinated by the intellectual discoveries which one's reading suddenly reveals, and there is probably a good bit of hero worship too. Later, all but a tiny fraction of those who make it through the academic mill learn that they have to settle for less than grappling with the very deepest questions, at the very frontiers of knowledge, and for some like myself there can follow a period of relative disappointment. But eventually I think most scientists accept themselves and their capabilities and find that whatever the field or the level there are unending challenges. Of course one works not *only* because one wants to *know*—one works very much also for the esteem of one's peers, and I use the word advisedly. Mercifully no analytical chemist compares himself with Einstein, and that makes it possible to find one's new paths not only on the very mountain tops but also in many a half-wild valley. Curiously this need for appreciation usually gets abstracted and internalized, at least in part, and becomes an internal standard, often far more severe in its judgment than any external judge.

In all honesty I think that most scientists consider the potential usefulness of their work as secondary. It is nice to feel that we may not be drones, but we would probably want to be scientists even if we were. Similarly, I think few scientists feel guilty about the misuses of science and its bastard daughter technology, even though, like myself, they can be pretty upset about such things. I don't want to roll out old chestnuts about science being valueless, and scientists do have social responsibility like everyone else and more, since they at least ought to understand the potential implication of scientific results better than others but it seems absurd to condemn the urge to know. What must be condemned all too often is the urge to do the wrong thing with that knowledge, but that is something else again. Finally, at least for my generation the relative affluence many of us now enjoy, thanks to the Russian launching of Sputnik I, has been something quite unexpected. And although we do enjoy it, it had nothing to do with career choice. In fact, at the time quite the contrary.

Probably the most accurate way to sum up motivation is to say that it is very much like that of the artist. Perhaps that sounds like an evasion, but it is not meant to. There are many similarities between art and science although, from the selfishly subjective view point of the scientist, many differences too. For one thing no scientist, not even Einstein or Newton, can make unique contributions. Sooner or later someone else would have made the same discoveries, had the same insights. In this respect science differs froms art, despite the similarity of the subjective feelings of scientist and artist in the act of creation, simply because there seems to be a regularity and an inherent logic in the realm of physics which, almost by definition, is not inherent in art. There is no way to escape the special theory of relativity, or quantum mechanics, once one starts down the road pointed by Newton, but no inescapable logic leads from Bach's St. Matthew's passion to Beethoven's last quartets, and even less from the great fugue to anything that has come after. A work of art can be *sui generis,* unique, despite the fact that in art as in science there are leaders as well as the led that art evolves. But there is no absolutely prescribed path which sooner or later, no matter what detours or shortcuts one takes, *must* be encountered again as in physics.

The closest physics comes to art is in the importance of point of view. A new point of view, of looking at what is already understood in a different way is usually the point of departure for new discoveries. This can be true of experimental work as of theory. Yet the new knowledge lies under the surface, ready to be mined. It is only a question of time. And that of course is what achievement in science boils down to. Who knows how many centuries physics might have lain dormant without Newton? By the time of Einstein in 1911 it would probably have been a matter of 10 years or less to the theory of relativity. The theoretical work of Minkowski, Lorentz, and Fitzgerald, and the Michelson-Morley experiment had laid the groundwork. By 1924 quantum mechanics was in fact discovered simultaneously by Schroedinger and by Heisenberg, although Heisenberg's way of saying the same things looked different. So the uniqueness which is Beethoven's or even Gibbon's seems denied to scientists. And yet scientists can be immortal too. For there are styles in science as much as in art, and when I read a paper by Willard Gibbs or Enrico Fermi the man is there and speaks to me, and Gibbs is not Fermi nor Fermi, Gibbs.

Have I exaggerated the uniqueness of art and artists relative to science and scientists? Probably yes, in the sense that despite the total absence of necessity for any given specific work of art there may be a psychological logic which inexorably demands certain general forms of expression. After all the music of Palestrina is as unthinkable in the 19th century as that of Chopin in the 16th. And just as certain discoveries could have been made in rather different ways, so certain general modes of expression would probably have been arrived at via rather different individual pieces of art. And just as we admire a great work of art for itself rather than for the style it represents, so scientists admire a fine piece of research as much for its ingenuity and elegance as for its importance in the larger scheme of things.

* * *

The meeting is over, my talk today went reasonably well; the size of the audience has been adequately reassuring. Anne and I are treating ourselves to a good dinner. We have enjoyed Kyoto immensely. For Anne it has been more of an adventure than for me, since her excursions and encounters have taken her farther afield than me, who has met only the kind of Japanese I have already known. Highlights of Anne's week: Nara, the capital of Japan before Kyoto, and getting around there with no English speakers or understanders anywhere near; a non-commercialized tea ceremony, to which she is taken by some of the Kyoto professors' wives she has met, who are impressed by her knowledge of Japanese history. The teamaster turns out to be a Ph.D. in physical chemistry who has given up chemistry to devote himself exclusively to the nurture of Japanese traditions; a Noh play.

* * *

We have gained a day; it is still Saturday. There is a certain relaxation to being on American soil again, to know exactly what to expect of immigration, customs, taxi drivers, hotels, and, God save the mark, newspapers. We are also travel weary and glad to do little more than lie in the sun for a while. Our hotel in Waikiki is near but not on the beach; unlike the pleasure palaces on the ocean it is unpretentious and quiet. It is amazing how much unpleasantness can sometimes be avoided simply by paying less. Our veranda faces West so that we can see both the ocean and the mountains inland. Rather, we would be able to see the mountains, which I remember vividly from my first visit here 15 years ago, were it not for the new high-rise development which lies between them and Waikiki. These new buildings are beautiful in a futuristic, unhuman way, as if they had been designed for and by giant moon ants. The lush, Gauguin-like backdrop of mountains and tropical vegetation heightens the slightly nightmarish impression of the whole. For me this housing in this setting epitomizes America's genius and its curse: The spirit of enterprise that knows no limits, born of the frontier and the land's boundless wealth, the spirit which brought cars for the millions and moon shots, and also Vietnam and the cementing of America.

Waikiki beach is pretty much as I remember it, but there seem to be more hotels. The same bored Hawaiians are taking hotel guests for outrigger and catamaran rides, the same complimentary cocktail and lei routines are unwinding for today's arrivals, distinguishable from yesterday's crowd by the absence of lobsterpink coloration. The sand is crowded, the water empty. To the mix of lonely secretaries and uxorious, overfed, and underexercised Midamericans has been added a large infusion of Japanese of all ages and waistlines, happily taking each other's pictures against Diamond Head. Their importance here is obvious. Not a shop or restaurant on Kalakua Avenue is without its bilingual displays or its prices marked in yen. The local papers abound with discussions of Japanese currency restrictions for tourists, and the revaluation of the yen.

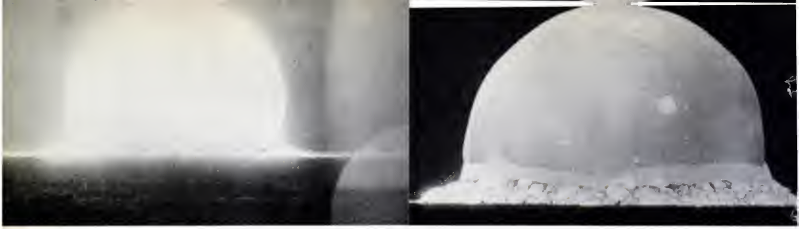
When I visited Oahu in 1959 on my way to Australia one could still get a feeling of the wide Pacific, an inkling of Polynesia, of other isles over the horizon beyond the lazy great swells and it occurred to me how beautiful Hawaii must have been in the time of the sailing ships. That summer the first commercial jets crossed the Pacific and this too marked the end of an era. Henry Kaiser had recently started 'developing' Oahu. Today the process is pretty well complete and the island is little more than a super-Southern California, with touches of Miami thrown in for good measure.

We have rented a car and are driving around Oahu counterclockwise, through the lush preserves of the wealthy around Diamond Head, past a Hilton, around Koko Head, on to a totally deserted five mile long crescent of beach at Waimanolo, where we swim and enjoy the luxury of being alone even though there are houses just beyond the sand. Then on along the North East coast; lunch in a Mexican restaurant in some little town, across from a Kroger Mart; for some reason the town reminds me of the country back of San Diego, Escondido, say. Then on to Sunset Beach, at the Northern tip, where the big breakers are. On the way a little indigenous culture, near Punaluu: a few decrepit shacks and a birth control information center for natives.

On the way South we turn inland, past the pineapple plantations. Much of the rich, red, volcanic soil is being torn up for housing developments and highways. There is even an Intertate-something-or-other. Anne asks me where it runs to and I tell her, Texas, of course.

With the exception of the public beaches and military reservations, there is not an inch of coast line that is not 'developed,' meaning in private hands. It is curious how many people accept the argument that conservationists and Sierra clubbers are elitist and land developers democratic.

A few hours later we are on our way to Los Angeles, which extends to San Bernadino now, and not long after that over Chicago, which now extends to Elgin. We are home. ☐



The first atomic bomb: 0.006 sec. **0.016 sec.**

'ALL IN OUR TIME'

A foul and awesome display

KENNETH T. BAINBRIDGE

My first view of the Trinity base camp was in January with David Anderson when we sought a location for an SCR-584 radar to try to follow the ball of fire if the test were successful. A sergeant brought a Weasel by truck from Los Alamos and met us at the north end of the Sierra Oscura. He drove us up through a snow storm. The snow flakes got bigger, the snow got deeper, and with increasing altitude, the trees got closer together and finally blocked our passage. We returned to the valley where I had my car. Anderson and I entered the test area. At that lower elevation the snow had become rain. Slithering on the soapy adobe road we passed through the barracks area and returned to Socorro without being challenged.

It was Security's hope that the Trinity site would not be associated with Los Alamos, 230 miles away. But trailer-housed itinerant workers, indigenous to that part of the country, recognized Lt. H. C. Bush and many others at Trinity whom they had known at Los Alamos. When the small group of U.S. Army Engineers did not have the special equipment needed for some construction work, contracts had to be let to civilian firms in order to meet the increasingly tight schedule.

In the autumn of 1944, the plan for a camp completed in December called for housing 160 military and civilian personnel. But on June 1, 1945, in addition to military camp personnel there were 210 scientists and technical aides, 250 by the middle of July, and a total of 425 on the weekend of the test, and a few special guests. We had asked Groves to keep his VIP list below 10 in number.

Instrumentation of Test

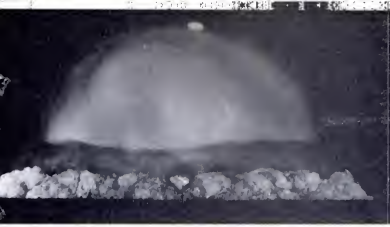
Victor F. Weisskopf was the chief consultant on plans for instrumentation of the test. He supplied and updated the predictions of the expected yield of the implosion bomb and its radioactive, optical, physical, and nuclear effects—properties essential to planning all of the measurements. Later in 1944 Enrico Fermi joined for nuclear experiments, and in the spring of 1945, William G. Penny advised on blast problems and Joseph O. Hirschfelder on fall-out expectations.

Every new suggestion of a useful measurement was considered on the basis of value, time scale for completion, and available personnel and shop time. Some overlap was allowed for the simpler experiments. The advantage of redundancy was great. No delay of the implosion test on the first practicable date could be supported on the basis, "Our experiment is so important that the test must be delayed until we are ready."

There were really three classes of experiments scheduled. One set of tests was prepared to obtain

---

Kenneth T. Bainbridge, who is George Vasmer Leverett Professor of Physics at Harvard University, was in charge of the first test of a nuclear bomb in the desert at Alamogordo, N.M., on July 16, 1945. This is the second and final installment of his account of the test. It also concludes a series of reminiscences of 12 nuclear pioneers begun in the Bulletin *in April 1974. The editor of the series, Jane Wilson, will present some observations on the reminiscences next month.*



0.034 sec.

0.053 sec.

measurements on blast, optical, and nuclear effects and characteristics. Another set, for which Robert R. Wilson, Bruno Rossi, Kenneth Greisen, Ernest W. Titterton and others were making preparations, was for a more detailed study of the implosion process and a check on the detonators, which would be of great value if the implosion should be imperfect. The measurement on the simultaneity of detonation of the explosive lenses was my least favorite experiment, as it meant that the test bomb was more complicated than the final "production" units, and that the chance of irregular predetonation by pick-up from lightning or any other factor was increased.

A third category was an experiment of great significance for the proposed explosion and for monitoring future atmospheric nuclear explosions anywhere. Herbert L. Anderson had worked it out. He had suggested a radio-chemical method for measuring the yield of a fission weapon. Later it appeared that a great amount of useful information could be obtained from the fall-out of nuclear explosions anywhere in the world. We were able in 1945 to pick up the Hiroshima explosion using specially equipped B-29s in California. Altogether there were some four long-range detection methods of which we tried three in 1945.

It was information on fall-out which was presented to President Truman in September 1949 as proof of the first successful Russian test of a bomb in the atmosphere. This method, available to anyone in the world properly trained in the techniques, was used quite independently by a Japanese physicist to give particularly important scientific results after the first U.S. hydrogen bomb test. I heard in November 1973 that details of the method are still classified by the Atomic Energy Commission.

Anderson proceeded with his idea and secured the aid of Nathan Sugarman's chemistry group from Chicago, which included D. Engelkemeier, S. Katcoff, J. Miskell and A. Turkevich. A mock-up of 1,000 curies of dissolved reactor fuel was used in the May 7, 1945, rehearsal test at Trinity. Herb Anderson's experiment did not need and could not be complemented by another experiment. His group was ready and all they needed was a yield of nuclear energy of any amount whatsoever.

In the summer of 1944, I was convinced that a rehearsal was imperative as there would be only one chance with the main test. A proposal was made to Oppenheimer for a test of 100 tons of explosive, to check our instrumentation and facilities, to calibrate gauges, and to determine weaknesses in the plans and organization. There did not seem to be any properly instrumented prior tests anywhere in this range of 100 tons. Also it was known that explosions above a few tons of TNT would have different blast and scaling characteristics than were well known for smaller explosions. At first opposed to more work and complication, Oppenheimer soon agreed to plans for a rehearsal shot. He later went out of his way to thank me for this insurance to enhance the chances for success of the Trinity explosion.

The 100-ton rehearsal shot planned for May 5 was detonated on May 7. The center of the 100-ton pile was 38 feet above the ground to scale effects to conform to the final implosion test bomb on a 100-foot tower on the basis of the then predicted yield. Kistiakowsky's division obtained special fast-acting explosives arrayed in the cylindric cubic structure of TNT to improve the speed and uniformity of the explosion. As Kisty told me, these explosives were not sensitive to mechanical shock, which was proven when (a) some boxes fell off a truck transporting the explosives from the rail siding at Pope, and when (b) some boxes fell off the elevator while I was taking a movie record standing on the stairs above the platform while Lt. Bush and his Military Police constructed the array.

The rehearsal accomplished what we had hoped for, or feared. We needed decent roads as the increased traffic for two weeks before the rehearsal had turned the scraped adobe roads to dust which got into everything. One expert-come-lately, eager to add an experiment, drove a car under our low wires and over unburied cables, resulting in last minute breakage and frantic repair to correct the damage. John Williams defined in detail the canine and questionable ancestry of the expert to his face which he took without a whimper. Communication facilities were insufficient or broke down. Other real troubles and some gripes came out in a meeting at Los Alamos.

Groves agreed to putting down 25 miles of blacktop road at $5,000 a mile, enough to provide a waterproof seal over the adobe and caliche. The new roads provided a superlative example of

0.100 sec.

1.0 sec.

planned obsolescence. Built to last three months, they started to break up 92 days after completion. Hundreds of miles of wire were on low poles off to one side of the road so that checking and repairs could be made rapidly at any location. Every one or two hundred yards two poles were raised and the wires elevated to give safer passage to any car or truck. Cables were buried. The rehearsal shot had gone off 1/4 second early due to electrical pick-up. This would have been costly in the final test where so many of the results depended on programmed timing down to the last millisecond. This provided one more reason to rule that after four weeks prior to the final test date no new experiments would be added to avoid new wiring with attendant pick-up hazards. Four weeks had been arrived at on the basis of two weeks for installation of new experiments and two weeks to engage in the final tune-up and rehearsals, including a few with B-29 planes from Kirkland Field.

All personnel, except those in the arming party, would be required to clear out of the area within 10,000 yards of Point Zero two hours before the scheduled detonation time. Walk out if a car broke down, but get out!

The night of the successful rehearsal shot was the one and only time at Trinity that I had an alcoholic drink until a few days after the final bomb test. Lieutenant Bush, John Williams and I relaxed at a poker game with John H. Anderson who joined us when he could. Anderson was a civilian security agent I was told. What his job was I never asked and he never volunteered to define. He didn't act like a psychiatrist. We were feeling good because the explosion had been satisfactory and no one was hurt. In the midst of our celebration, a rocket went off.

There were rockets with wires attached for use as a trial sampling technique to recover plutonium and fission products in a drag cup after the real test, and one of Herb Anderson's group had picked that night to try one out as he considered it safe to do so now that the 100 tons of explosives were gone. Goodby fun and games! I found Herb Anderson and together we loaded the remaining rockets into a truck and drove to one of our explosives magazines where they were stored and firmly locked up.

In March and in part of April and May, the lower urgency schedule was about as follows: Up at 5 a.m., breakfast; off to work at 6 a.m., an early lunch; office work when the day's heat around 1 p.m. was too much for physical work outdoors; back to the test area, returning to base at 5 p.m. After supper every day during the week there would be a session on construction led by Williams with Sgt. A. H. Jopp (wiring), Sgt. Gibson (construction), and some group leaders present to report on what had been done and what priority jobs had to be tackled the next day. Sergeant Jopp, a line man for a power company by trade, was the only man who knew where the 500 miles of wire started and stopped. He was side-swiped and knocked down but not injured by a 5-ton Mack truck driven by the only woman working at the site during a flurry of gravel hauling for construction.

After the evening meeting a poker game generally followed, ending at 11 or 12 p.m. The outdoor air and exercise seemed to serve as a substitute for sleep. It was only the last month before the test that contributed to physical and nervous strain to any great degree, largely because there was no time for relaxation.

In the middle of May, on two separate nights in one week, the Air Force mistook the Trinity base for their illuminated target. One bomb fell on the barracks building which housed the carpentry shop, another hit the stables, and a small fire started. Fortunately the barracks occupied by soldiers and civilian scientists were not struck. If the lead plane hit the generator or wires and doused the target lights, then the succeeding planes looked for another illuminated area. This must have been what happened in May of 1945. After all, the crews had come at least a thousand miles to pass their final exam and had probably never been told of anything except targets in the area.

We had requested two SCR-584 gun-director radars and operating crews. This was the radar suggested by Louis Ridenour and developed by Ivan Getting at the MIT Radiation Laboratory which helped to bring down some 90 percent of the V-1 rockets.

Worried about the destruction of all our efforts if some budding bombardier should later destroy the test bomb with a hit on the tower, I asked Robert Oppenheimer if we couldn't convince the next batch of military planes or the occasional curious individual plane to stay away by firing smoke

2.0 sec.

4.0 sec.

shells ahead of any intruders to demonstrate that *forbidden area* meant just that. An SCR-584 gun-director radar and gun battery could safely lead ahead of planes and scare them off. This suggestion was vetoed as too risky, but by this time I had little conviction that orders to stay away from our area would be obeyed.

Telephone communication from Trinity to Los Alamos was a time-consuming and frustrating experience. Under the security rules the connection had to go through a special operator in Denver, identified by some such number as 15023, who would make the connection to Los Alamos without mentioning the name. If one ever got to this operator, as usually the first operator encountered had never heard of 15023, one would be rewarded usually with a very noisy line, full of cross-talk, which was frequently interrupted. Finally, late in May, we got a teletype connection. Until then, the greatest enjoyment we had and shared with the MPs, in whose office the telephone was located, was on those occasions when one of the group leaders in frustration would shout louder and louder to be understood and, then, demand, "Diddle the operator, diddle the operator"—an attempt to have the recipient of the call take over the task of getting a better connection.

Richard C. Tolman and General Thomas F. Farrell paid a visit later in May. They stayed in the infirmary where there were civilized beds. The infirmary was one end of a barracks building with an obscene sign above the entrance as an advertisement. They invited me in for a discussion and report on how things were going, asked what they could do to help, and gave me a friendly between-the-haves fight talk. Then they made an impossible request which, I believe, must have been Groves' idea originally. Essentially they ordered me to keep Robert Oppenheimer away from the tower and the bomb before the final test for his own safety, and not let him know I was trying to do it. No way! The bomb was Robert's baby and he would and did follow every detail of its development until the very end.

The next day Jumbo was due to arrive. I drove Dick Tolman over the desert to greet our black elephant at the siding at Pope, the 5 by 6 by 8 foot shelter station on the Santa Fe. Soon the train came into view, an engine and tender, flat car, Jumbo on its special massive car, followed by another flat car, and the caboose housing the security men, guards, and train men. Security had ordained that a huge tarpaulin be strapped over Jumbo and down to the sides of the car. Sometime during the might, the huge bottle had been scraped by a signal tower, station roof, or something which had cut the tarpaulin all along one side. The security men seemed surprised and upset.

Jumbo represented to many of us the physical manifestation of the lowest point in the Laboratory's hopes for the success of an implosion bomb. It was a very weighty albatross around our necks. After we had welcomed Jumbo appropriately, Dick Tolman asked to take the wheel to drive back and we returned the 30 miles to Base Camp.

We decided to put Jumbo 800 yards north by west away from Point Zero on the chance we wouldn't use it but could if necessary. The rehearsal shot had been located 800 yards on the south side of Zero. Our main layout was unencumbered to receive the 100-foot tower to support the bomb.

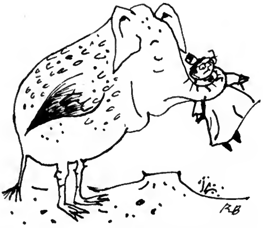
Count Down

Early in July, Oppenheimer had told me of the approaching meeting beginning July 15, of Truman, Churchill and Stalin. A successful test was a card which Truman had to have in his hand.

> The schedule for the test was such that as soon as the plutonium for the bomb was ready, everything else should be ready and the test would be held. There was a little delay but not much. Instructions from Washington were that no day was to be lost and it wasn't. The nuclear assembly and final explosives were completed at Alamogordo and the shot was scheduled for July 16. (R. F. Bacher, "Robert Oppenheimer," *Proceedings of the American Philosophical Society*, 116 (1972), 219.)

E. M. Purcell and Victor Weisskopf showed theoretically that the SCR-584 radar would probably have only a range of a mile or two, insufficient to follow the rise of the ball of fire expected after the detonation. A trial would be made anyhow, and the radar before the detonation still retained its important function of providing wind velocities at all levels as it followed balloons carrying small corner reflectors.

We were fortunate to secure Captain Marvin Allen who arranged for some Army searchlights to follow by simple triangulation the ball of fire and



Jumbo was a very weighty albatross around our necks.

mushroom cloud by night, or by day with an attached optical finder. No electrical pick-up troubles would be incurred as the searchlights were located miles away from Point Zero and the test area wiring. Precise location of the searchlights and radars was a necessity. With some further exploration, I found bench marks at several locations proving that not all the mapping of New Mexico had been done in the backrooms of frontier saloons, as frequently appeared to be the case.

The ranch roads which Frank Oppenheimer and I had located, and mapped on orders from General Groves for use as escape routes from the Base Camp, were considered by the General impassible in spots and were scraped for some miles. Frank and I were used to day or night driving in the desert and anything not traversed by arroyos had seemed serviceable to us.

Herb Anderson's experiment required that one way or another samples of the earth in the crater would be collected as soon as possible after the bomb explosion. One hope had been to use a semi-rigid dirigible, or a blimp, to lower a grab bucket to pick up samples as a backup for the rockets. Unfortunately those available would not behave very well at the high altitude and desert temperature conditions with their bases so far away. The few helicopters available at that time didn't have enough operating leeway to do much beyond support the pilot. We also had in mind a blimp or helicopter as a rescue vehicle if we used a shielded tank to recover samples of sand. If the tank should get stuck in highly radioactive sand, it would be well to get the driver and scientist-passenger out of there in a hurry. As the aerial rescue methods were canceled out, preparations were made to shield two tanks with lead, one for the reconnaissance and one held in reserve as a rescue vehicle. Unfortunately on July 16, only one tank was operative.

Activities had quieted down somewhat on the 15th. One or two weeks of rehearsals and timing trials were coming to a close except for a few groups who had more difficult measurements to perform. The bomb was now on the tower and the Base Camp was bulging so that many people who had worked hard at Los Alamos and had every right to witness the test were required to go to a location at Compagna Hills about 20 miles away from Point Zero. David Dow was in charge of that site and had a shortwave radio to hear the final countdown at the frequency for ground-to-B-29 communication from S 10,000. The frequency was meant to be different from that of any licensed station. Unfortunately, Security had allotted us the Voice of America's frequency. Our FM radios, which several guard stations, the Base Camp and many jeeps and cars were equipped with for local communication, had been assigned the frequency of the railroad freight yard in San Antonio, Texas. Though far away, we could hear them shifting freight cars by number and presumed that they could hear us. The Socorro Airport listened in too.

Sunday supper, July 15, ended in a general meeting at which a colonel on General Groves' staff gave suggestions on how to avoid eye damage, being knocked down by the blast, and how to evacuate the Base if fall-out came that way.

I had been in the test area nearly all day. Back at the Base I was furious to hear of discussions of the possibility that the atmosphere might be detonated. This possibility had been discussed at Los Alamos and had been quashed by intensive studies of all possibilities by Hans Bethe and others. It was thoughtless bravado to bring up the subject as a table and barracks topic before soldiers unacquainted with nuclear physics and with the results of Bethe's studies.

The idea of runaway nuclear energy was not new. In 1903 Rutherford had quipped, "Some fool in a laboratory might blow up the universe unawares." A. S. Eddington in 1920 first suggested that the source of the Sun's energy might be the conversion of hydrogen to helium. Commenting on this in 1922, Aston wrote on the general problem of nuclear energy, and on fusion particularly:

> Should the research worker of the future discover some means of releasing this energy in a form which could be employed, the human race will have at its command powers beyond the dreams of scientific fiction; but the remote possibility must always be considered that the energy once liberated will be completely uncontrollable and by its intense violence detonate all neighbouring substances. In this event the whole of the hydrogen on the earth might be transformed at once and the success of the experiment published at large to the universe as a new star. (F. W. Aston, *Isotopes* (London: Edward Arnold and Co., 1922).)

"Neighboring substances" certainly included the atmosphere. We all put our faith in Bethe.

My personal nightmare was knowing that if the bomb didn't go off or hangfired, I, as head of the test, would have to go to the tower first and seek to find out what had gone wrong. I had had a minor

My personal nightmare was knowing that if the bomb didn't go off or hangfired, I, as head of the test, would have to go to the tower first and seek to find out what had gone wrong.

taste of this sort of thing. At Los Alamos I participated in a test on a full-scale implosion bomb with an inert core. The idea of that test was to shoot 20-mm cannon shells into the explosive-containing casing as a test of what Japanese fighter pilots might do to a real bomb over Japan. Shots were fired and the explosive lens assembly did not blow up.

Roger Warner, who was one of those with me at the time, and I waited for what I thought was a long enough time. We then walked out of our protective barricade to inspect the damage, but soon after we left smoke started to curl out of the holes in the casing. This induced a rapid retreat to shelter. Nothing more happened for a long time so we withdrew to let the bomb sit for a few hours. Later we did inspect it, and blew it up to get rid of it. Apparently, a direct hit on a detonator might be necessary to make the bomb blow up, but a fire could do equally well in the case of a confined explosive. The smoke we had seen earlier indicated that by good luck only a small amount of explosive had burned.

Arming Party

The first possible time for the detonation of the real bomb had been set for 2 a.m. July 16, and the Arming Party was scheduled to arrive at Point Zero—the tower supporting the bomb—before 11 p.m. July 15. At that hour, Don Hornig would connect the cables to the bomb and detach the detonating unit used in rehearsals. Inasmuch as Louis Hempelmann, Paul Aebersold and I were the "Entry Permission Group," which was formed to decide who might enter the test area to recover records after a survey had been made of levels of radioactivity following the blast, I had no idea when I could finally return to barracks on the 16th. So about 8 p.m. on the 15th, all duties having been fulfilled to that time except the ultimate one of arming the bomb, I asked the M.P. Sergeant on duty to wake me up at 10 p.m. and went to my barracks to get some sleep. The weather prognosis was poor.

When the time came to go to Point Zero, I drove Joe McKibben and Kistiakowsky in my car; I had selected them to be in the Arming Party. Jack Hubbard, Sergeants W. Stewart and J. C. Alderson—the weather group—went in a truck or car with their equipment. Bush and Sgt. Lloyd took a third vehicle; they were there, I believe under General Groves' orders, to prevent possible last-minute sabotage attempts and give assistance if needed.

On the way in, I stopped at S 10,000 and locked the main sequence timing switches. Pocketing the key I returned to the car and continued to Point Zero. Soon after our arrival, Hornig completed his work and returned to S 10,000. Hornig was the last man to leave the top of the tower.

The weather men got to work with their instruments and balloons to get the wind speed and direction, humidity and temperature at all levels to 20,000 feet above our ground location (5,000 feet above sea level).

Sporadic rain was a disturbing factor. Every once in a while Bush or Lloyd would flick a flashlight around the tower, or one of us would leave the car to see that no activity was going on except the work of the weather group. Kisty went to the first landing on the tower to re-adjust a light as an aiming point reference for the cameras at W 10,000. Jack Hubbard gave progressive forecasts well ahead of the possible time for detonation. At midnight our earliest possible 2 a.m. shot had to be canceled. Soon everyone was told to get out of the test area as we might shoot at 4 a.m. Then zero time set for 4 a.m. was washed out. A telephone on one leg of the tower was linked to Williams at S 10,000. When it got too wet at the telephone, I would return to the car near the tower in which Bush, Lloyd, Kisty, and McKibben were located. If Williams had something to report, he called me by radio and I could return to the telephone. Security.

We had none of the lightning reported by those at the Base Camp about 16,000 yard away or at S 10,000, but it made interesting conversation as many of the wires from N,S,W 10,000 ended at the tower. Williams insulated me from whatever the tensions were at S 10,000. Finally, just before 4:45 a.m., Hubbard gave me a complete weather report and a prediction that at 5:30 a.m. the weather at Point Zero would be possible but not ideal. We would have preferred no inversion layer at 17,000 feet but not at the expense of waiting over half a day. I called Oppenheimer and General Farrell to get their agreement that 5:30 a.m. would be $T = 0$.

Then Williams came to the phone. We had arranged that I would report each step taken in the arming process so that if anything went wrong, he would know what had been at fault. I drove McKibben to W 900 so that he could throw the timing and sequence switches there while I checked off his list. Returning to the base of the tower, I reported to Williams again and threw the special arming switch which was not on McKibben's lines. Until this switch was closed the bomb could not be detonated from S 10,000. The final task was to switch on a string of lights on the ground which were to

"Now we are all sons of bitches."

serve as an "aiming point" for a B-29 practice bombing run. The Air Force wanted to know what the blast effects would be like on a plane 30,000 feet up and some miles away, simulating a bomb drop and scramble from the target area. The plane, dodging thunderheads, was not in proper position, but was 15 or 20 miles away when the bomb went off.

After turning on the lights, I returned to my car and drove to S 10,000, arriving about 5:00 a.m. The next step was to broadcast the wind velocity and elevation data to Compagna Hills, N and W 10,000. With the weather the way it was, only the higher elevation data was good at points other than Point Zero.

I unlocked the master switches and McKibben started the timing sequence at -20 minutes, 5:09: 45 a.m. At -45 seconds a more precise automatic timer took over. At the final seconds another circuit, designed by Titterton, sent out electronically-timed signals for the still more precise pulses needed by many special instruments.

At -30 seconds I left the S 10,000 shelter and found Bill Elmore 20 yards away, who let me use a section of his sheet of foam rubber to lie down on. We all had welder's goggles and I looked in the direction of Little Burro Peak which was to the right and behind me.

The bomb detonated at T = 0 = 5:29:45 a.m. I felt the heat on the back of my neck, disturbingly warm. Much more light was emitted by the bomb than predicted, the only important prediction which was off by a good factor. When the reflected flare died down, I looked at Oscuro Peak which was nearer Zero. When the reflected light diminished there I looked directly at the ball of fire through the goggles. Finally I could remove the goggles and watch the ball of fire rise rapidly. It was surrounded by a huge cloud of transparent purplish air produced in part by the radiations from the bomb and its fission products. No one who saw it could forget it, a foul and awesome display.

I had a feeling of exhilaration that the "gadget" had gone off properly followed by one of deep relief. I wouldn't have to go to the tower to see what had gone wrong. I wouldn't worry any longer: Had everything been properly anticipated? Was there one lousy soldered joint which had separated for some reason? Had some important circuit grounded because of the rain? Had someone in the final hours of activity, handicapped by fatigue, gotten careless and made the wrong connection or substituted a dummy unit used in rehearsals for the proper final unit?

After the blast wave had passed, I got up from the ground to congratulate Oppenheimer and others on the success of the implosion method. I finished by saying to Robert, "Now we are all sons of bitches." Years later he recalled my words and wrote me, "We do not have to explain them to anyone." I think that I will always respect his statement, although there have been some imaginative people who somehow can't or won't put the statement in context and get the whole interpretation. Oppenheimer told my younger daughter in 1966 that it was the best thing anyone said after the test.

Within an hour only a small group remained at S 10,000. The rest had returned to the Base Camp three miles away.

After the ball of fire had gone into the 30,000 to 35,000 foot region, it was apparent with increasing daylight that some radioactivity had been trapped below the 17,000-foot above-ground inversion layer which Jack Hubbard had observed by his weather balloon measurements. We also knew that when the Sun rose, cool air came down into the valley. I remember some rapid calculations of the hazards assuming that a small percentage of the fission products would be caught in a volume of air 3 miles high, 6 miles wide, and 12 miles long. Two or three hours after the explosion, when the Sun heated the central valley air. Hempelmann's counters began to click more and more rapidly at S 10,000. We put on dust masks as the counting rate increased. Finally the radioactivity decreased as the air was slowly swept away.

J. G. Hoffman or Aebersold made surveys of the roads to Base and the Compagna Hills and one of them went with me on the two roads leading from W 10,000 and S 10,000 to Point Zero. When the radioactivity on the ground approached a dangerous level we turned around and came back to S 10,000. It was apparent that few of the records buried in protective bunkers could be recovered that day. Also the success of the test and some immediately available test results meant that there was no great hurry anyway. The only entry to the vicinity of the crater would be made by Sgt. Bill Smith and Herb Anderson in the shielded tank, so Hempelmann and I didn't have much more to do after the tank returned safely from the hazardous trip.

I got into my car at about 3 p.m., straying off the road once, and returned to my bunk to sleep it off. I did chance to see E. O. Lawrence who, after congratulations, gave me a present of a bottle of precious bourbon which was hoarded until I could appreciate it. □

Copyrighted material

Four approaches to technology assessment

"Society and the Assessment of Technology," by François Hetman. Organization for Economic Co-operation and Development, Paris, 1973. 420 pages. $9.50.

"Environmental Harrassment OR Technology Assessment," by Derek Medford. Elsevier, New York, 1973. 358 pages. $15.95.

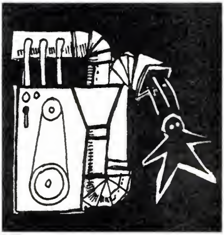
"Technology Assessment in a Dynamic Environment," ed. M. J. Cetron and B. Bartocha. Gordon and Breach. New York, 1973. 1,036 pages. $49.50; paperback, $20.00.

"Technology Assessment and Quality of Life," ed. G. J. Stöber and D. Schumacher. Elsevier, New York, 1973. 302 pages. $15.50.

Reviewed by
ALAN L. PORTER and STEVEN H. FLAJSER

The passage of the National Environmental Policy Act of 1969 (NEPA) and the 1972 act creating a Congressional Office of Technology Assessment (OTA) are two of the most significant events in the evolution of American technology policy. The legislation indicates that a culture long weaned on the faith that technological advance automatically leads to social satisfaction is moving through a winter of discontent over the many negative consequences of technology. As a society, we are going beyond the traditional questions put to technologies—are they technically feasible and economically profitable—to ponder whether they are socially desirable. Moreover, desirability is to be determined by systematically looking at the widest possible range of technological impacts that are both intended and unintended, direct and indirect. Such is the mission behind the label "Technology Assessment" (TA). The question before us is to what extent has the spring of TA arrived: Is technology assessment ready to cast its light upon the policy-making processes of society?

Assessment of the potential consequences of technological changes has been practiced historically in such forms as engineering and marketing analyses and has been incorporated into various business and governmental processes. The notion has been extended in scope by the provisions in NEPA for environmental impact statements. Now, a new body of literature, prompted largely by Congressional initiative, is concerned with the extension and integration of such efforts to assess the probable impacts of technological alternatives. The present barrage of four volumes has been preceded by various publications including key reports by the National Academy of Sciences, National Academy of Engineering, the Library of Congress, the MITRE Corporation, an anthology edited by Raphael Kasper, as well as a new journal, *Technology Assessment.*



This literature addresses information needs for several audiences—assessors, the users of assessments, government administrators, corporate managers, teachers and students, special interest groups, and numerous publics. These different audiences variously require information on such aspects of TA as the problems and opportunities that technology poses for society (that fostered TA); historical development; and present concepts, methods, and state of the assessment art. We assess the four works against these perceived reader needs.

The four volumes frame TA in different contexts. Stober and Schumacher treat TA in terms of its relationship to the quality of life; Medford nominally views it in terms of environmental concerns, but the treatment is primarily economic; Hetman tries to be eclectic in his view, although he, as Medford, is rather economically oriented; Cetron and Bartocha present TA from multiple perspectives.

The books are not only interesting for what they choose to include and how they do it but also for what they choose to deemphasize or omit. The authors all share an international vantage point from which they advocate TA, although they are mindful of its present limitations. With the exception of Medford, however, the books all

---

Alan L. Porter is assistant professor in the School of Industrial and Systems Engineering at the Georgia Institute of Technology, Atlanta; and Steven H. Flajser is research assistant professor in the Program in Social Management of Technology at the University of Washington, Seattle.

lack careful organization, editing, indexing, and clarity of writing. It is as if each were rushing to be first in print. In a substantive vein, we found several elements generally underdeveloped: implications of the weak theoretical and empirical base for TA, ramifications of extending benefit-cost analysis to less objective measures, difficulties in valuing the trade-offs in impacts identified, and concern with the special needs of potential users of TA, particularly affected publics. Above all, the authors do not indicate how the success or failure of TA can be gauged.

Hetman's *Society and the Assessment of Technology* provides the most concise and comprehensive treatment of the information areas noted previously. It is the textbook of choice (in terms of price as well as content). Hetman's synthesis of an imposing amount of useful material employs an assortment of frameworks to set forth conceptual, methodological, institutional, and user considerations. Most significant, he provides detail sufficient to guide the reader's first attempts at application. He also raises the key issues: generating relevant data within the constraints of available knowledge, time, manpower and money; realistically deriving inferences from such data; and finally estimating the appropriate degree of confidence for such inferences. Most important, he clearly recognizes that TA is "putting values to technologies." However the entire effort reads like a draft. But it is a usable book that will hopefully warrant a second edition to provide Hetman the opportunity to polish it into a first-rate text.

THE CASE FOR A NUCLEAR MORATORIUM

presents the argument for a moratorium on the construction and operation of nuclear power plants. The Environmental Action Foundation's publication, **The Case for a Nuclear Moratorium,** discusses the political and technical aspects of a moratorium as well as the alternative energy sources currently available. Authors include John W. Gofman, M.D., Ph.D., Senator Mike Gravel (D-Alaska), and others.

Send $1.00 per copy to:
The Environmental Action Foundation
Suite 724, The Dupont Circle Building
Washington, D. C. 20036

Name No. of Copies
Address
City State Zip Code ★

Medford's book *Environmental Harrassment OR Technology Assessment* is not as comprehensive as Hetman's, but in certain areas it is exacting and stimulating. Although Medford never addresses the title of his book, he does discuss the historical development of NEPA and OTA. The role of information search activities is interestingly highlighted.

What Medford does best is to elaborate mathematical techniques, including benefit-cost, cost-effectiveness, technological forecasting, and models for assessment of basic research. This makes for heavy reading at times, however. Overall, Medford provides a valuable quantitative rigor but not a consolidated, broad perspective.

Cetron and Bartocha's *Technology Assessment in a Dynamic Environment* is a massive anthology suffering from an uneven selection and an organization that defies comprehension. Nonetheless, it offers a considerable number of valuable pieces, many reprinted.

Stober and Schumacher's collection, *Technology Assessment and the Quality of Life,* fulfills one important function. It places TA in juxtaposition with the notion of quality of life indicators (social indicators), thereby emphasizing the necessity of social, as contrasted to purely economic, assessment. In addition for those readers who enjoy conferences, here is one in print, the Fourth General Conference of *S*alzburg *A*ssembly: *I*mpact of the *N*ew *T*echnology (SAINT).

If these books fall short of expectation, the cause lies in part with the state of development of technology assessment. The authors had to deal with TA's unresolved needs for greater knowledge about the interrelationships of complex physical and social systems, conceptual clarification of its scope and substance, successful adaptation of the sundry techniques into viable coherent methodologies, and evaluation of the practical effectiveness of alternative methodologies.

We share the authors' optimism for the success of technology assessment. However, TA's development into an important influence will depend first on the fullfillment of those unresolved needs by the assessors. Second, no matter how competent the analysis, it will only count (for better or for worse) if it affects the decision-making processes. Responsibility for the assessment of technology assessment hence rests with both the practitioners and their clients. Because of society's critical need to deal more wisely and humanely with technological change, those of us betting on TA's ability to improve decision-making—and hence the quality-of-life—hope that the TA ground-hog bodes an early spring.

Genetics at the crossroads

"Genetic Fix," by Amitai Etzioni. Macmillan, New York, 1973. 276 pages. $7.95.

Reviewed by
R. D. O'Brien

The decision to press ahead with research to create nuclear bombs was made by a few individuals during a period of extraordinary stress. Biology is on the verge of presenting us with other decisions of tremendous moment, particularly in the area of manipulation of human genetic material, which is the topic covered by this book. But these decisions are being debated openly and internationally and the big decisions will be made by legislatures, caught in a cross-fire between a sometimes uninformed public and a body of scientists facing conflicts between their eagerness to understand and the possible social consequences of such understandings. *Genetic Fix* is an account of important basic facts about the status of human genetic engineering and the attitudes of a distinguished group of biological and social scientists to those facts, as evaluated by one of them.

Autobiographical Novel

This is a remarkable book in several ways. It may be the only readable book ever to be based upon a scientific conference.* Etzioni is not a practitioner of the subject-matter of the conference: he is a sociologist, not a biologist. The book is a blow-by-blow account of the conference, but Etzioni brings together what each participant said and how the audience responded with how he feels about it. All this is set in the form, with something of the style, of an autobiographical novel—with no shortage of pithy comment. For example, speaking of J. Lejeune's response to one paper, Etzioni remarks: "Like many true believers, who come to meetings primarily to make their own opinions felt, he unrolled his banner whenever the opportunity arose."

The earthy commonsense remarks in this book are refreshing after the profundities of theologians and scientists on this subject. For example, speaking of the possible threat which embryo transplants pose to the sanctity of the family, he says, "If the family survived several million instances of adultery a year, would several thousand test-tube matings undo it?"

Etzioni deliberately avoids didactic conclusions. And the scientific facts in the book will be known to all who read Newsweek and the New York Times conscientiously. Indeed, as the book was published in 1973, such readers would be ahead of the book in this fast-moving field. But the basic ethical problems are chronic, touching on a whole variety of questions: Should we attempt to breed a superior race? On which day does a human egg, embryo, fetus or newborn acquire legal rights, so that its disposal (if imperfect) can be performed with equanimity? Is it proper to buy a tiny frozen embryo to have it implanted (perhaps in a 'mercenary'), so that one can choose one's child's hair color, size and IQ? Is there, in this era of adoptions and overpopulation, a right to reproduce? If there is not, then is it proper to allocate the financial and human resources of medicine to the problem of infertility, as if it were an illness? Should the increasing predictive value of amniocentesis (sampling of the amniotic fluid to study the fetus' chromosomes) be used, along with abortion, not only to reject mongoloid fetuses but to permit other choices (especially sex), which chromosomal studies can reveal?

Etzioni backs the various proposals recommended at the conference—at both national and international levels—for standing commissions, such as a National Board of Biomedical Research Ethics in the United States, or an "international nongovernmental body to explore and study the moral and social issues raised by new and forthcoming developments in biology and medicine." But WHO and UNESCO declined to "be identified with its creation or direct support." Since the book was published, however, the U. S. Congress has enacted legislation to establish the National Commission for the Protection of Human Subjects of Biomedical and Behavioral Research. At least some of Etzioni's concerns come under the purview of this group.

R. D. O'Brien is Director of the Division of Biological Sciences, Cornell University.

---

*The conference, "Recent Progress in Biology and Medicine - Its Social and Ethical Implications," was sponsored by the Council for International Organizations of Medical Sciences (established under the auspices of the World Health Organization (WHO) and UNESCO), and held in September 1972 in Paris.

REMEMBERING THE BULLETIN

As a non-profit endeavor, the Bulletin of the Atomic Scientists depends for its continued effectiveness on the contributions of its many friends and readers. Remembering the Bulletin in your will can be a fitting way of making an enduring contribution to the magazine and its important work.

Bequests should be made payable to the Educational Foundation for Nuclear Science, Inc., which publishes the Bulletin. They are fully tax-deductible for federal estate tax purposes. The following wording is suggested for general purpose bequests: "I give, devise and bequeath to the Educational Foundation for Nuclear Science, Inc., a not-for-profit corporation under the laws of the State of Illinois, and having the principal office at 1020-24 East 58th St., Chicago, Ill. 60637, the sum of $______, or the following described property, ______, to be used for its general purpose."

Individual circumstances can affect the nature of your bequest. For additional information consult your attorney or the Bulletin office.

BULLETIN
of the
ATOMIC SCIENTISTS
1020-24 E. 58th St.
Chicago, Il. 60637
(312) 363-5225

ALL IN OUR TIME

THE REMINISCENCES OF TWELVE NUCLEAR PIONEERS

The Bulletin of the Atomic Scientists

A Collector's Item

The recollections of 12 nuclear pioneers, published in the Bulletin of the Atomic Scientists over the past year, have now been brought together in a handsome volume. Articles by Otto R. Frisch, Luis W. Alvarez, J.H. Manley, Philip H. Abelson, Albert Wattenberg, Herbert L. Anderson, Martin D. Kamen, Boyce McDaniel, Frederic de Hoffmann, Val L. Fitch, R.R. Wilson and Kenneth T. Bainbridge. With an introduction by Jane Wilson and drawings by Rainey Bennett. Available now in a form you will want to keep and at a price you can afford. Soft cover, pocketbook size.
$3.45

Order now through the
BULLETIN OF THE ATOMIC SCIENTISTS

Bulletin of the Atomic Scientists
Dept. A-55
1020-24 East 58th St.
Chicago, IL 60637

Please send me ______ copies of
All In Our Time @ $3.45
(10% discount on orders of 10 or more).

All orders must be prepaid

NAME ....
ADDRESS ....
....
CITY .... STATE .... ZIP ......